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Mining Royalties and the Iron Trades: Some Conditions of Foreign Competition.

By T. GOOD.

ALTHOUGH there is little cause for the alarm bordering on panic that is being entertained in certain high quarters concerning the industrial and commercial future of Britain, it would be absurd to deny that there is any ground for uneasiness. The latest particulars to hand in reference to the world's trade in iron and iron goods distinctly prove that we are not keeping pace with our competitors, or at least, we are not making the progress in iron production and manufacture that is desirable. Competition from America, for the moment, it is true, is not so keen as was the case a year or two ago, or even a few months back; but this is simply owing to a temporary restriction of output of pig-iron in the United States, through the financial troubles of the Steel Trust—disturbances which are bound to be adjusted in due time, when American exports of iron goods will again be on a large scale. It would be unwise, therefore, to allow ourselves to be lulled into a false security. Competition from the Continent is here, and will become keener; and competition from America will shortly return more vigorous than ever, and this competition will have to be dealt with. We must set about earnestly and diligently to find ways and means of placing ourselves in a better position to hold our own in the world's trade in iron and steel, or otherwise be content to lag further and further behind.

And that we are being left behind there is little question. The world's demand for iron goods is increasing much faster than the world's population is increasing, but we are getting but the merest fraction of this growing trade in iron; in fact, placing our imports of iron and iron goods against our exports, or applying the test of iron production per head of population, or drawing a comparison between the development of the iron industry at home and that abroad, it can easily be seen that we are making no progress whatever, either actually or comparatively. In the production of pig-iron—the foundation of our shipbuilding, engineering, and kindred trades—we have made no headway during the last ten, twenty, or thirty years. Twenty-four years ago the output of pig-iron for the United Kingdom was $4\frac{1}{2}$ cwts. per head of population, against

Germany's 1 cwt., and the United States' 1¼ cwts.; now the annual production is 4½ cwts. per head in the United States, 4 cwts. in the United Kingdom, and 3⅓ cwts. in Germany. But we are rapidly losing the second position on the *per capitum* basis, as we have already lost it on the basis of actual production with our output of 8¾ millions of tons last year, as against Germany's 10 millions, and America's (U.S.) 18 millions of tons. For whilst our output is practically stationary, that of our competitors is largely increasing both actually and relatively. Whilst nearly, if not fully, one-third of our blast-furnaces have been idle, the latest returns from Germany show that, of 313 completed furnaces in that country, no fewer than 297 were in blast. During the last twenty years or thereabouts, the production of iron has been increased in France by 30 per cent., in Belgium by 50 per cent., in Germany by 300 per cent., and in the United States by 400 per cent., whilst ours is just about where it was in the early "eighties." And although we must admit that we have been somewhat slow to adopt the most up-to-date appliances, yet I shall endeavour to prove that the most powerful factor responsible for our relative stagnation, in contrast to the remarkable progress of our rivals in iron, is to be found in the conditions of our heavy mining rents and royalties compared with the much lighter charges obtaining abroad. But before dealing with this point I seek to further emphasise the imperative necessity for drastic reform in the foundations of our iron industry.

It is not the intention here to argue that exports are a true test of prosperity, or that foreign markets are more valuable than home markets, but it must be conceded that in our tables of imports and exports we have much evidence that calls for attention. Ignoring the temporary increase in our exports of iron goods through the financial difficulties of our American rivals which have already been mentioned, we have to face a competition that cuts two ways: not only are we being elbowed out of markets abroad in which there is an increasing demand for iron goods, but we are being undersold in our home markets. This is not as it should be. Taking a period of, say, 25 years, and summarising the position and development of the British iron industry, as revealed by our imports and exports, little of a satisfactory nature can be found. Our exports of machinery have increased, it must be admitted, but not so rapidly by any means as has the world's demand for machinery. Our total exports of iron and steel, and manufactures thereof, have shown but a slight actual increase, whilst per head of population they have materially declined, and, relatively to the world's demand, and comparatively to the trade of other iron-producing countries, our exports have considerably decreased. And against this fact we have recorded a four-fold increase in our imports of iron and iron and steel goods! For instance, our exports of hardware and cutlery have decreased by nearly one-half in 25 years, despite the increase in population with its concurrent demand, and now we are spending a million a year in foreign hardware and cutlery where we used to spend nothing. Our exports of implements and tools have increased, but not in proportion to the growing demand abroad for these things, and even this increase in our exports appears now to have stopped, and we are importing largely under this heading. Even in shipbuilding, where we have held, and yet hold, a unique supremacy, we are being more seriously challenged every year. Our output of new shipping in 1902 amounted to nearly 500,000 tons more than that of all foreign countries put together; but last year the difference was only 177,000 tons.

That other nations are using their hands and brains, developing the resources of their countries, and competing with us is quite natural. And this competition may prove beneficial; in fact, we need competition and opposition to spur us to improvement. That America has some natural resources superior to our own will be readily conceded, although these are considerably exaggerated from time to time, as most things American usually are; but that we should be so rapidly overtaken by people no more favoured than ourselves by Nature is a fact providing ample food for thought. Surely,

what can be done on the Continent of Europe—leaving America out of the reckoning for the moment—to create, maintain, and develop the iron industry, can be done here!

On the subjects of improved methods of working, methods of production, and methods of business, the British workman, manufacturer, and merchant have each a plethora of candid friends continually tendering advice gratis, and advice at so much per column; therefore these questions shall not be laboured just now by the present writer, who begs to indicate other directions in which improvements should and must be looked for, although, as a practical man, he claims to be much better acquainted with the shortcomings of the British workman and the British employer than the average writer upon these questions. But, whilst there is plenty of blame attaching to these individuals, there is another audience to which we should address some of our strongest remonstrances. I allude to our landlords.

Some ten years ago our Iron Trades' Delegation, upon their return from the Continent, reported that, in their opinion, if British ironmasters enjoyed the same railway rates and mining royalties as those of their Continental rivals, foreign competition could be defied. What has happened since then? In 1895 the United States got ahead of us for the first time in iron production, and have since *doubled their output*. Last year Germany also got ahead of us for the first time, and is going further ahead, whilst we remain "as we were." And unless we intend not only not to go forward, but to go backward in the near future, we have got to tackle these mining royalties.

In the shape of various charges known as fixed rents, dead rents, lease fees, wayleaves, water-leaves, air-leaves, and royalty per ton, we have levied upon our minerals, and upon the coal we consume in the manufacture of these minerals—a list of extraordinary, extravagant, and exorbitant tariffs which handicap us to a very considerable extent both at home and abroad. These various charges just named, to group them under one heading—for they are all royalties upon, and add to the cost of, mining—represent a tax of not less than 1*s*. per ton of coal; and this is in turn a tax upon the general industry of the country, and especially upon our iron and steel makers, who use so many tons of coal in the manufacture of a single ton of finished goods. On the most moderate computation it is possible to make the royalty charges on a ton of British pig-iron exceeds 5*s*. on the average, and in some districts approaches 10*s*. per ton; whilst such charges in those countries with which we have now got to compete, represent but the merest fraction in the cost of production.

Sir Isaac Lowthian Bell, in his "Principles of the Manufacture of Iron and Steel," estimates the royalty on a ton of pig-iron from limestone, ironstone, and coal to be 6*s*. in Scotland and 6*s*. 3*d*. in Cumberland. And this estimate is an extremely moderate one. A ton of West Yorkshire iron pays 6*s*. per ton in royalty, reckoning the royalty to be only 1*s*. per ton on ironstone, 6*d*. per ton on coal, and 3*d*. on limestone. But the royalties in that district average nearer 1*s*. 4*d*. on ironstone and 1*s*. on coal. However, taking the lower figures, we are handicapped with a royalty fully *ten times higher* than is our German rival.

In Germany mining royalties are fixed by the State at 2 per cent. on the profits of the undertakings; in Belgium at 2½ per cent. on profits; and in France—all coal and ironstone being the property of the State—at 5 per cent. on profits, whilst rents are merely nominal, being about ½*d*. per acre, as against our rents of from £2 to £5 per acre on the top of lease-fees, often exorbitant and sometimes prohibitive. In Spain also mining rights are leased on merely nominal terms, and in the United States mining royalties, etc., are practically unknown, and land with its minerals has been bought clean out for £1 an acre.

Now let us see what these mining royalties mean to us in competition with Germany, from whom we have more to fear than from America even—at least for some time to come. Suppose we realise a profit of 2*s*. per ton of coal in our mining

operations—or, what will serve our purpose in illustration better, suppose we make no profit whatever, as has sometimes been the case, we still have a royalty charge of 1*s.* per ton on the average, in any case. But if our German rivals make 2*s.* profit their royalty will be ½*d.*; if their profit is 1*s.* their royalty will be but ¼*d.*; and if they make no profit they pay no royalty. But in our case, whether we make profits or not, whether we can or cannot hold our own in the matter of price with our foreign competitors, our landlords' charges have got to be met, or we must cease operations—capital and labour suffering indiscriminately in consequence. Now if it is right and proper to urge our workmen to improve their conduct, and lecture our manufacturers about not spending their last penny in up-to-date machinery, surely it is not unreasonable to ask our landlords also to stretch a point in the national interest while there is yet time?

These mining royalties—not to mention ground rents and heavy capital charges thrown upon our railway companies through excessively dear land, and which are reflected in high transit-rates—have been a burdensome indirect tax upon our manufacturing trades when we have had no competitors seriously challenging our supremacy; but now that we are being hard pressed these charges are rapidly reaching prohibitive point. I know of a firm in the county of Durham who pay nearly, if not fully, £80,000 a year in mining royalties on the materials they use, whilst a firm using the same quantity in Germany or Belgium would not pay £3,000 in such charges. And this is not an exceptional but quite a typical case. I could quote the case of a Lancashire firm who paid as much as £100,000 a year in mining royalties, when, had they been a Continental firm, they need have paid not a penny, for they were making no profits. I was acquainted with a Yorkshire firm who paid from £10,000 to £20,000 a year in royalty alone, not to mention rents, etc., but whose shareholders for nine consecutive years were without a dividend, and at length they ceased operations. A few months ago I was on an estate in the Tyne district where I saw a mine idle, the plant and machinery in a state of decay, and the cottages deserted, simply through excessive rents, royalties, and way-leaves which could not be met during a period of temporary slackness. The system of granting mining leases in this country is positively oppressive compared with that prevailing in other countries. Of course all landlords are not stone-hearted, but many of them show little sympathy with our national industries. A mining lease is conceded for a term of years upon certain conditions as to fees, rent, royalty, way-leave, etc., mutually agreed upon by tenant and owner; but when the lease is expired, and the tenant company—their plant in full working order—desire a renewal, it is only granted on the landlord's terms, and if trade happens to be good at the time these terms are often based on "boom" figures. Then, in the course of a few years, if prices fall and the owner is not of a generous disposition, the inevitable collapse comes—investors are ruined, workmen are turned adrift, and the plant becomes the property of the landlord. We hear a great deal about Land Bills and Fair Rent Courts for Ireland: it is time a move was made on behalf of the industries of Great Britain.

Surely this state of affairs constitutes a solid grievance. In face of the fact that we tolerate such an unfettered monopoly in our land and minerals as is not suffered by any of our leading competitors, can we wonder that our exports of iron and steel goods per head of population are declining, whilst our imports of iron and steel and manufactures thereof are increasing at an alarming rate? Whilst our own furnaces are damped, foreign iron is being "dumped." I have no wish to overstate the case, or to preach any gospel of confiscation. I am fully aware, as a practical man, of other circumstances that tell against us, and of other dangers ahead; but I respectfully submit that when, as is already the case, we have some of our mines idle, nearly one-third of our blast-furnaces blown out, and many steel works and rolling mills on "short time"; when we have much capital unremunerative, and labour unemployed; and when at the

same time other countries are going ahead by leaps and bounds in iron production, and we are using larger and larger quantities of foreign-made iron and steel; and when we have mining companies paying nearly as much in rents and royalties as they pay in wages and salaries, *and even more in some cases*, and frequently more than they pay in profits—some firms, in fact, having to cease operations on account of prohibitive royalties—it is high time for attention to be called in unmistakably plain language to these conditions, which are slowly, but none the less surely, undermining the very foundations of the British iron industry.

The Theory of Steam Turbines.—II.

By FRANK FOSTER, B.Sc.

(Continued from p. 380.)

Vane Forms.

We have now to determine the forms to be given to the vanes in a turbine of the De Laval type. Referring to Fig. 10, v is the absolute velocity of the steam as it leaves the steam-nozzle, its direction making an angle θ to the direction of motion of the wheel which is moving with a velocity V. In the diagram, $A\,B$ is the steam velocity and $C\,B$ the wheel velocity. Then $A\,C$ is the velocity of the steam relative to the wheel. A particle of steam starting from A at the same instant that a vane starts from C would meet that vane at B, and would obviously enter the vane at an angle α as given by the inclination of $A\,C$ to $C\,B$. Hence α is the angle of entrance to the vanes, that is, the angle the entering lip of the vane makes to the plane of the wheel.

Since there is no further expansion of the steam, then, neglecting friction, the relative velocity of the steam at exit ($C\,D$ in figure) will be the same as the relative velocity ($A\,C$) at entry. Then, completing the parallelogram $D\,C\,B\,E$, $C\,E$ must be the absolute velocity of the steam in magnitude and direction at exit, since it is compounded of the velocity with the wheel and the velocity relative to the wheel. The work done on the vane

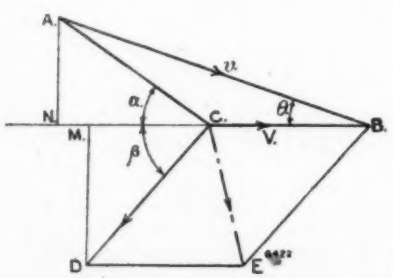


FIG. 10.

equals the kinetic energy in the steam before entry, minus the kinetic energy after exit

$$= \frac{1}{2g}\left[A\,B^2 - C\,E^2\right]$$

The component velocities perpendicular to the direction of motion of the wheel at entrance and exit respectively are: $A\,N = AB \sin\theta$ and $M\,D = C\,D \sin\beta$.

These velocities, multiplied by the areas of the openings between the vanes and divided by the volume of one pound of steam at these points, give us the weights of steam passing into and out of the wheel. These are obviously alike, and since it is usual to make the opening at entrance and exit equal, we must make α and β equal. This has the advantage that the vanes, being symmetrical, there is no end-thrust along the shaft. By making the vanes deeper at exit than entry we should make β smaller than α, and hence reduce CE, the velocity of the steam leaving the wheel. This would make the turbine a little more efficient, but would introduce an end thrust, and too small a value for β is undesirable if the steam is to properly clear the wheel. The effect of the friction of the steam against the vanes is to reduce the relative velocity at exit, so that β would have to be slightly greater than α, unless the depth of the vane at exit be somewhat greater than at the inlet. The latter is preferable.

If α and β are equal, then the work done per pound of steam is $\frac{2}{g}(v\cos\theta - V)\,V$ and hence the efficiency is

$$\frac{\frac{2}{g}(v\cos\theta - V)\,V}{\frac{v^2}{2g}} = \frac{4\,V\,(v\cos\theta - V)}{v^2}$$

This has a maximum value when $v\cos\theta = 2V$. The angle θ which the nozzle makes to the wheel must not be made too small, or the steam will have difficulty in

entering the wheel. It is 20 degs. in the De Laval turbine. From this it follows that the angles of the vane, α and β, must each be 36 degs., and the velocity of the wheel should be 0·47 that of the steam. Save for non-condensing turbines—which are very uneconomical—this is an unattainable velocity. The effect of running at too slow a speed is to cause losses by breaking up the steady motion of the steam, and also to lower the efficiency by sending the steam into the exhaust with a higher velocity. The loss from this latter cause is not very great within fairly wide limits of variation of the wheel speed.

We have already briefly noticed how the difficulty of the high-wheel speed is surmounted in the Curtis turbine by having a series of alternate wheels and guides, each wheel absorbing a fraction only of the kinetic energy.

Fig. 11 gives the construction for determining the shapes of the guide and wheel vanes. As in the previous diagram, $A\,B$ is the velocity of the steam leaving the nozzles, $C\,B$ is the wheel velocity, and hence $A\,C$ is the velocity of the steam relative to the wheel at entry. $C\,E$ is the actual velocity of the steam as it leaves the first wheel and enters the first set of guides; hence $C\,E$ gives the inclination of the entering lip of the guides. The guides then change the direction of the steam's motion to $E\,F$, but, except for the effect of friction, do not alter the magnitude of the velocity. Hence $E\,G$ gives the velocity of the steam relative to the second wheel at entry and α_2 the inclination of the vanes at entry on the second wheel. The construction is similar for the succeeding wheels. $G\,H$ is the absolute velocity of the steam leaving the second wheel. It is usual to make the wheel vanes symmetrical, but different for each wheel. The guide vanes will not in general—if ever—be symmetrical, but an end thrust on the turbine casing is of no consequence. It is advisable in designing such a turbine to make some allowance for the reduction in velocity due to the friction of the steam against the vanes, since the design is no more difficult to get out or the turbine to construct.

Without at present going into detail we

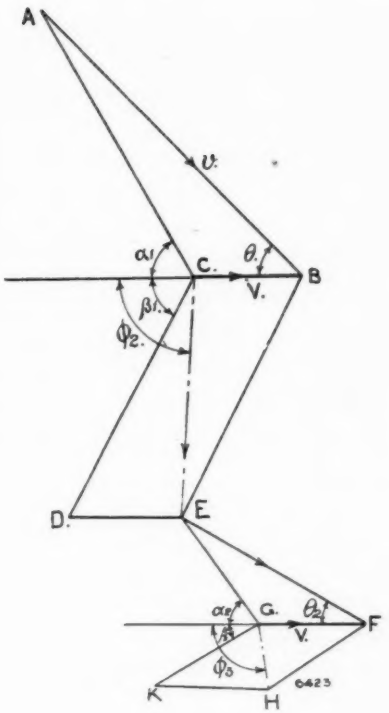


FIG. 11

may divide the losses in a steam turbine into three divisions:

(1) Leakage from the turbine and radiation.

(2) Losses in the nature of a resistance to the rotation of the wheels, *i.e.*, friction of bearings and of the wheels rotating in the steam.

These losses require to be overcome in exactly the same way as any other load on the turbine.

(3) Losses peculiar to the turbine, or *turbinic* losses, that is, those due to the rejection of kinetic energy to the exhaust — usually very small — to the skin-friction of the steam passing through the vane passages, and to the eddies produced in the steam due to the breaking up of the

moving steam by the imperfectly formed passages and to leakage past the vanes.

The losses of the last class determine what we may call the *turbinic* efficiency, as distinguished from any efficiency in calculating which losses of the first two classes are included. In the Parsons, and probably also in most other turbines, this turbinic efficiency never exceeds 70 per cent.; if, indeed, it ever attains that value, 50 to 60 per cent. being a more usual value. For instance, a 500-kilowatt turbine took 20 lbs. of steam per kilowatt hour. Assuming the efficiency of the dynamo at 93 per cent., the mechanical efficiency of the turbine—allowing for wheel and bearing friction, to be, say, 90 per cent.—then the mechanical efficiency of the whole is 83 7 per cent., and the steam per h.p. is 12·45 lbs. If, then, we assume leakage and radiation to be responsible for ·45 lb. (3·6 per cent.), and knowing that the theoretical consumption of steam is 7·5 lbs., we see that the turbinic efficiency is 62·5 per cent. This means that of the available energy in the steam 3·6 per cent. is lost by leakage and radiation from the turbine, and about 32 per cent.—allowing about 2 per cent. for loss to exhaust—is converted into heat. This heat, together with that produced by the friction of the rotating wheels, is spent in drying or superheating the steam, thus increasing the volume at the same time that it reduces the velocity; this should be allowed for in designing a turbine. The remaining 62·5 per cent. is converted into "indicated" work on the turbine-shaft.

If, in getting out the design of a turbine, we assume the expansion to be adiabatic within the turbine, and the velocity of the steam to correspond, the forms of the passages will be incorrect, and will increase the losses.

To allow for this in the design of a Curtis-type turbine, we might (Fig. 11) make $C\,D$ 5 per cent. less than $A\,C$; that is, assume the skin-friction of the vanes to reduce the velocity of the steam by 5 per cent., we might then allow for a loss in eddies of 5 per cent. in passing from the wheel to the guides, another 5 per cent. in the guides, and another in entering the next wheel; in this case $E\,F$ will be 15 per cent. less than $C\,E$. From this we can determine the angles of the guide and wheel blades, making the latter symmetrical to avoid end thrust — that is, make α and β alike.

For instance, suppose we have a Curtis-type turbine divided into stages. In the first stage the pressure is lowered by the nozzles from 135 lbs. absolute to 59 lbs. absolute. Then, by the method described in the first article, we know that the theoretical velocity of the steam leaving the nozzle is 1,800 ft per second, and—assuming the steam dry initially—from the entropy diagram the moisture present is 6 per cent. Assume that the friction and eddies in the nozzle reduce the velocity to 1,735, then the heat generated by this friction will evaporate some of the moisture, leaving $5\frac{1}{2}$ per cent. In passing from the nozzle to the wheel we assume 5 per cent. of the velocity to be lost—again slightly drying the steam—so that the velocity of the steam entering the wheel is 1,650 ft. per second. Let us take the wheel velocity at 300 ft. per second. We can now determine the shapes of the vanes, making allowances for friction losses as indicated above. We have considerable latitude as to the angles of the guides. In this example the writer took the exit angle of the first two guides—or, rather, nozzles and guides—to be 45 degs. This determines the other angles for the first two sets. The angles of the guides for the third wheel were in this case the last; and, in order to secure that the steam leaving the last wheel should have no velocity save parallel to the shaft, it was necessary to make the angles of the vanes very acute—probably too acute for practice. The results are tabulated on page 461.

The velocities and angles are determined by the construction as outlined in Fig. 11. To obtain the losses we simply calculate the loss in kinetic energy, and divide by 778 to bring it to British thermal units. Thus the theoretical velocity of discharge from the nozzle is 1,800 ft. per second, so that the kinetic energy in each pound of steam should be 50,050 foot-pound-second units; the actual velocity is 1,735, giving

Table III.

Set.	1		2		3	
	Nozzles.	Wheel.	Guides.	Wheel.	Guides.	Wheel.
Angle, entrance (vanes) ..	—	53	65	59	81	19
Angle, exit, degs.	45	53	45	59	15	19
Velocity, entrance	—	1650	1170	1050	685	620
Velocity, exit	1735	1235	1110	720	650	150
Velocity parallel to shaft—						
At entrance	—	1165	1060	740	585	160
At exit	1225	1120	785	615	170	50
Volume per lb. of steam at entrance ...	—	6·78	6·84	6·88	6·91	6·92
Volume per lb. of steam at exit	6·75	6·81	6 86	6 90	6 915	6·93
Area of passages perpendicular to shaft—						
At entrance (sq. ins.) ...	—	9·6	10·65	15·35	19·5	71·5
At exit	9·1	10·05	14·4	18·5	67·0	228

Losses in British thermal units per lb. :—

1. In nozzle ... ... = 4·6
2. Between nozzle and wheel 1 = 5·7
3. In wheel 1 ... ... = 3·4
4. Between wheels 1 and 2 = 8·2
5. In wheel 2 ... ... = 1·1
6. Between wheels 2 and 3 = 2·7
7. In wheel 3 ... ... = ·05
8. To exhaust ... ... = ·5

Total loss ... ... = 26·2

$$\text{Turbine efficiency} = \frac{64{\cdot}8 - 26{\cdot}2}{64{\cdot}8} \ldots \ldots \ldots \ldots \ldots = 59{\cdot}5\,\%$$

46,500 units a loss of 3,550 foot-pound-second units or 4·55 thermal units. The latent heat of steam at this pressure (59 absolute) being 909·7, this heat will evaporate ·005 pound of moisture, correspondingly drying the steam and increasing its bulk. Since the weight of steam passing through the turbine is the same at all places, then, knowing the volume occupied by each pound, the number of pounds passing per second, and the velocity parallel to the shaft, it is an easy matter to calculate the cross sections of the passages, taken perpendicular to the shaft. The values in the table have been calculated for a 1,500-kilowatt turbine, to take an overload of 25 per cent., making the total capacity 1,875 kilowatts, and using 22 pounds of steam per kilowatt hour.

It will be noted how small the passage area is at most points, and hence it is necessary to blank up part of the guides. This is especially necessary in small turbines and in slow-speed—large diameter—turbines. Suppose we choose our revolutions per minute at 1,500; then, as we have chosen the wheel speed at 300 ft. per second, the mean diameter must be 4·77 ft. The larger the diameter the less will be the depth of the vanes, or the greater the number of blanked ports in the guides in order to keep the passage areas correct; and hence, for low powers —small passages—a small diameter and a high speed of rotation are necessary. As both narrow passages and blanked parts increase the eddy losses in the turbine, it follows that low-power turbines are inefficient—a fact which is assisted by the increased leakage past the vanes of such a turbine.

In the example worked out above the available energy in the steam between the pressures, 135 and 59 lbs. per sq. in., is 64·8 thermal units (per lb.); and hence the turbinic efficiency is 59·5 per cent., the turbinic losses being 26·2 thermal units. This efficiency is probably as high as that actually attained, although careful experiment and design should enable it to be improved on.

There are a few points worth noting in designing a complete turbine. In the first place, owing to the large increase in

the passage area as we get nearer the exhaust, and especially so just at the last, it is usually necessary to make the diameter of the wheels in each stage of expansion larger than those of the preceding stage; hence, being all on the same shaft, the wheel velocity is different for different stages. In order to simplify construction, we want the forms of the vanes for all the different stages to be alike; hence we must so adjust the drop in pressure at each set of nozzles that the velocity generated in them bears to the wheel velocity for that stage a ratio which is constant for all stages Thus, if the diameter in one stage is twice that in the preceding, the nozzle velocity of that stage must be twice that of the preceding. Reducing the diameter in this fashion reduces the necessity for blanking up, not only by decreasing the circumferential length of the passages, but also by reducing the velocity of flow through them.

The last set of nozzles should reduce the pressure to within about half-a-pound of the condenser pressure, consequently the volume of the steam delivered to exhaust will be very great.

A word or two on the blanking up of the guide parts is necessary. Obviously the wheel passages must all be free, and hence the question arises, What is meant by the area of the wheel passages? The area of the effective wheel passages is that lying between the passages of its two neighbouring guides. For instance, if the vanes on the wheel and guides all have the same pitch, and if the guides have (say) 8 and 12 passages respectively, then the wheel between them may be considered to have 10 effective passages. This determines the depth of the vanes on the wheel. It is important to note that the passages in one guide must not come just opposite those in the preceding guide; for, whilst the steam passes through the wheel, it is also carried forward with the wheel, so that it leaves the wheel further round, relative to the circumference of the casing, than where it entered. For instance, if the distance between the guides is 1·25 ins. and the velocity of the steam parallel to the shaft is half that of the wheel, then the openings in the next guides must be 2·5 ins. (measurements taken from the centres of the openings) in advance of those in the first set. If we define an opening as the whole of the passages between two blanked passages, then the number of passages in an opening on one guide should not be more than two in excess of those on the previous guide; as otherwise, they will not all be filled by the moving steam leaving the wheel. Probably an increase of one passage per opening would be better; in which case the number of effective passages on the wheel is the same as that on the previous guide. If it is necessary to increase the number of passages in one guide considerably above those in the previous, then the number of openings or sets of passages should be increased; but it is unadvisable, in view of the fact that the greatest loss due to this blanking up occurs at the boundaries of the streams of steam, to increase the number of openings—that is, the number of such boundaries. In any case, the openings must be arranged symmetrically round the circumference of the guides. If these points are not attended to we shall have the stream of steam delivered against a blank wall, or its width suddenly caused to increase, resulting in the bulk of the kinetic energy being destroyed and converted into heat (see Fig. 12).

The design of a Rateau turbine calls for no special mention, so far as vane forms are concerned. Each chamber consists of a complete De Laval-type turbine. The chief losses are due to the churning action of the wheels rotating in the steam, the friction of the passages, eddy losses, and the destruction of most of the kinetic energy in the steam as it leaves the wheel, a rather serious item in this turbine.

The Parsons turbine is very interesting, on account of the fact that the conversion of kinetic energy into work on the turbine shaft and the generation of kinetic energy go on simultaneously. Some latitude is possible with regard to the forms of the vanes, but it is very desirable for purposes of construction and repair that all the vanes should be alike, save as to radial

depth. They can then all be cut from the same rolled metal.

In Fig. 13 let the suffixes 1 and 2 stand for the entrance and exit of the wheel, 3 and 4 the same for the guides. As before—

v represents steam velocity (absolute);
V, wheel velocity;
u, volume occupied by 1 lb. of steam;
A, area of passages perpendicular to shaft.

The simplest way of proceeding is to assume that, of the available energy in the steam between any two pressures, about 60 per cent. (rather more in the largest sizes is admissible) is converted into useful kinetic energy, and to design the vanes on this assumption. The other 40 per cent. of the energy is spent in increasing the volume of the steam.

In the Curtis type of turbine practically the whole of the available energy in the steam was converted into kinetic energy, the losses taking place after this had occurred. In the Parsons turbine the velocity never really appears; that is to say, whilst the velocity is being reduced by friction it is being increased by a fall in pressure; so that we may just as well assume that there is no reduction of velocity, the energy liberated by the fall in pressure being converted, part of it directly into heat, and the rest into kinetic energy. Hence we get rid of the modifying effect of the losses at one stroke. This assumes that the generation of new kinetic energy and the wasting of old by friction go on side by side throughout the turbine. This is reasonably accurate; since, as we shall see, the kinetic energy generated in each wheel and each guide-ring in any one stage—the turbine is usually in stages—is the same, and probably the friction is also.

Referring to Fig. 13, AB is the velocity of the steam leaving a guide or entering the wheel $= v_4 = v_1$, AC is the velocity relative to the wheel at entrance, α being the inlet angle of the wheel vane. CD is the relative velocity of exit from the wheel, and β the angle of exit for the wheel vane. CE is the absolute velocity of exit from the wheel, and ϕ the inlet angle of the guide, θ its exit angle.

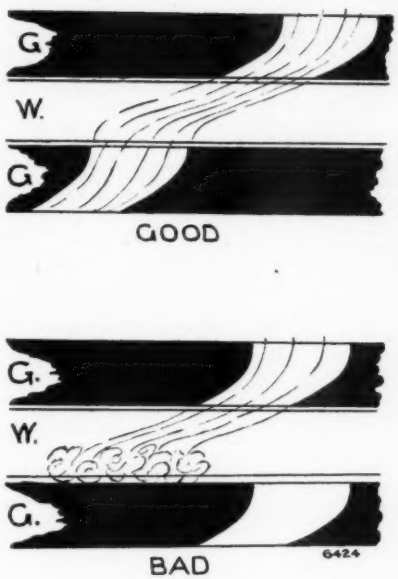


FIG. 12.

Then, v_1 and v_4 are the same, as also are v_2 and v_3.

Also, lbs. of steam entering wheel per second $= \dfrac{A_1 v_1 \sin\theta}{u_1}$ and this equals the weight leaving the wheel $= \dfrac{A_2 v_2 \sin\phi}{u_2}$

If now we keep the velocity of flow parallel to the shaft constant we have:

$$v_1 \sin\theta = v_2 \sin\phi$$

hence $$\frac{A_1}{A_2} = \frac{u_1}{u_2}$$

similarly $$\frac{A_3}{A_4} = \frac{u_3}{u_4}$$

that is, the area of the passages at any point varies directly as the volume of one pound of steam at that point.

We also want the vanes on the guides and wheels to be of the same form, that is θ equal β, and α equal ϕ. Now work done per lb. of steam on one wheel

$$= \frac{V}{g}\left[v_1 \cos\theta - V + CD \cos\beta\right]$$

$$= \frac{V}{g}\left[2\, v_1 \cos\theta - V\right]$$

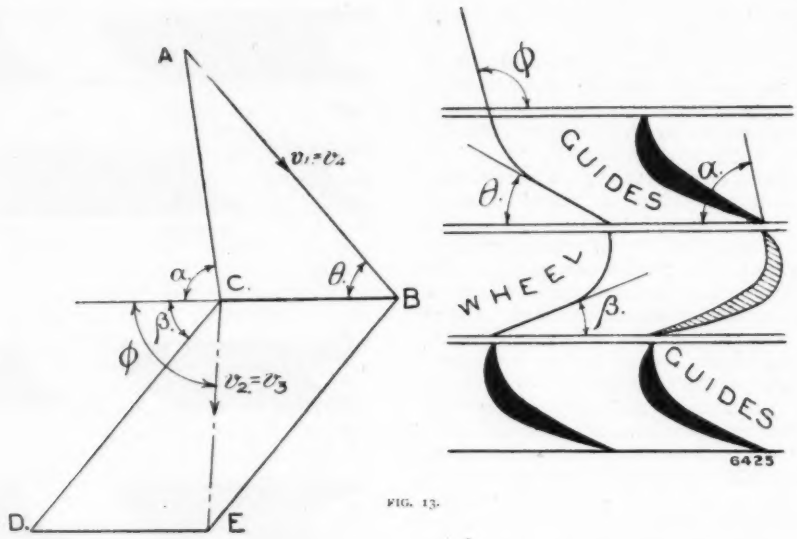


FIG. 13.

$= \frac{V^2}{g}$ when a and ϕ each $= 90^\circ$

kinetic energy generated in guides

$= \frac{v_3^2 - v_4^2}{2g} = \frac{v_1^2 - v_2^2}{2g} = \frac{V^2}{2g}$

kinetic energy generated in wheel = kinetic energy leaving wheel − kinetic energy entering wheel + work done

$= \frac{v_2^2}{2g} - \frac{v_1^2}{2g} + \frac{V^2}{g}$

$= \frac{v_1^2 - v_2^2}{2g} = \frac{V^2}{2g}$

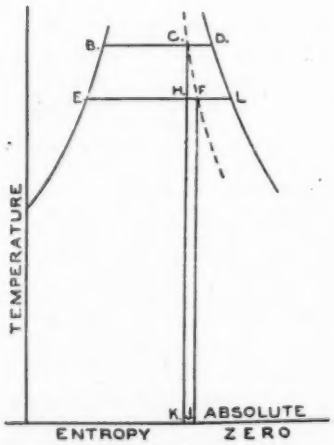


FIG. 14.

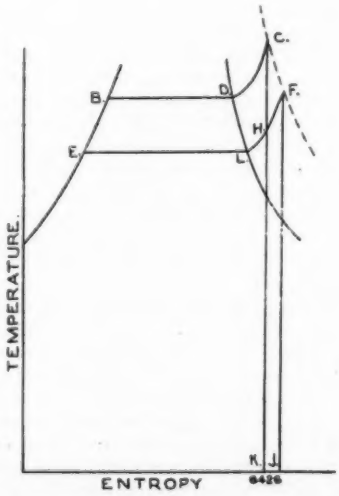


FIG 15.

That is, the kinetic energy generated in the wheel is the same as that generated in the guides. The angles of exit β and θ may have any suitable value, provided they are alike. Too large a value will mean an increased velocity of flow through the turbine, causing increased friction losses, and also a somewhat larger loss into the exhaust, although this last is seldom of importance; hence a small angle—say 20 to 30 degs.—should be chosen. Also the smaller this angle the larger will be the steam passages, and blanking up will be reduced, but the area subjected to skin friction will be increased. Experiment is necessary to determine the best angle.

If we take the same conditions as for the Curtis example, we see that the available kinetic energy in this stage is, say, 60 per cent. of the gross energy in the steam; that is, 38·9 thermal units, or 30,200 foot-lb. second units. Taking, as before, the wheel velocity at 300 ft. per second, the energy absorbed per wheel is 2,800 foot-lb. second units; so that, 9·3, say, 10 wheels are required, as against the 3 in the Curtis turbine. On the other hand, the sizes of the passages in the turbine will be larger than in the Curtis. The volumes of the steam per lb. at the several points in the turbine may be calculated or obtained from the entropy diagram (Fig. 14), the use of which greatly facilitates steam-turbine calculations. In the figure BC represents the initial pressure (in terms of temperature), EH the pressure at the point considered. Then the ratio $\frac{BC}{BD}$ represents the initial dryness fraction. The area $BCHE$ gives the total available thermal units between the pressures BC and EH. Since only 60 per cent. of this has been used the other 40 per cent. must have been converted into heat at the pressure EH. Draw the rectangle $HFJK$, having an area equal to 40 per cent. that of $BCHE$, then F is the state point of the steam at the pressure EH; and we can read off directly, or calculate from it, the volume of the steam. Thus, if u is the volume of 1 lb. of saturated steam at that pressure, the volume in this case will be $\left(\frac{EF}{EL}\right)u$.

We must now fix on a value for the exit angles of the turbine vanes, say 30 degs. Then the velocity of flow parallel to the axis is 300 sin 30 degs., or 150 ft. per second. The passage areas are then calculated exactly as in the case of a Curtis turbine.

If the steam had been superheated Fig. 14 would require a little modification (see Fig. 15). DC and LHF are constant pressure lines, calculated as described in the first article. Then we make the area $HFJK$ equal to 40 per cent. that of $BDCHLE$. F is a point on the expansion line. We require also the constant volume lines for superheated steam. Professor Perry gives the formula—

$$T = \cdot 0117\, p \left[u + \left(\cdot 118 + \frac{3200}{p + 3350} \right) \right]$$

where—

T = temperature Fahr. degs. (absolute);
p = pressure, lbs. per sq. ft.;
u = volume per lb. in cub. ft.

These formulæ for superheated steam must not be relied on too implicitly, but they are the best we have.

The New Vauxhall Bridge.

WHEN a representative body enters into the domain of constructive engineering and demands of its technical staff the performance of unaccustomed work, a good deal of useful experience may be obtained at the expense of other people.

This result has certainly followed the efforts of the London County Council in connection with the rebuilding of Vauxhall Bridge, a work which was commenced in 1898, and of which the only portions completed up to the present time are the foundations and masonry approximately up to high-water level. Some clue to the extraordinary delay which has occurred will be found in the history of the work which is now presented.

Our attention will first be devoted to the work comprised in Contract No. 1, which included the removal of the old bridge, the piling, concreting, foundations, masonry, and the complete erection of the new bridge up to the level of 9·75 ft. above ordnance datum.

The old bridge, commenced about 1811 and completed in 1816, under the direction of John Rennie, consisted of nine openings, each of 78 ft. clear, with a headway of 29 ft. above high-water level. This structure the County Council decided to replace by a concrete bridge. In view of the fact that it was desired to utilise the bridge for tramways it is difficult to say why concrete was chosen in preference to steel. Owing to the weight of a masonry bridge so built, especially secure and costly foundations are required, and owing to the flat gradient required for tramways a concrete bridge of properly proportioned span and rise, as contemplated by the Council, is impossible. In the plans prepared by the Engineering Department of the London County Council the spans vary from 130 ft. 5¾ ins. at the abutment to 149 ft. 7 ins. at the centre. Thus it will be seen that the openings are smaller than those in many masonry arches, and very much smaller than those of old fashioned cast-iron structures, such as Sunderland Bridge, completed in 1796, and Southwark Bridge, completed in 1819. If comparison were made with modern steel bridges, the disadvantage would be still more striking, and we entirely fail to understand why the Council should have adopted a mode of construction clearly calculated to cause unnecessary obstruction to the waterway of the river.

Unfortunately, the initial error of the Council was small when compared with the second blunder. The plans, specifications, cost, and indeed the practicability of the whole scheme were essentially based on the assumed fact that a solid bottom of blue clay extended at an average depth of from 20 to 25 ft. below the bed of the river.

From information already published we find that no adequate steps were taken by the Council to ascertain whether the clay actually existed at this level. Sufficient trial borings would have settled the matter without question, but this elementary precaution appears to have been entirely neglected, and the whole of the designs were worked out upon what is now conclusively shown to have been an utterly unwarrantable hypothesis.

Tenders were invited in due course, and the accepted contractors, Messrs. Pethick Brothers, commenced work at the Westminster end of the bridge, driving piles for the cofferdam around the site of the new abutment. Fig. 1 shows the position of the new Westminster abutment, and also indicates the old abutment together with the curved wing walls and other details. It will be seen that on the eastern side piling is driven continuously round, terminating in line with the back of the abutment, while on the western side it is carried only halfway along the side elevation. The total length of the abutment is 100 ft. 3 ins.

and its width 56 ft., but the length at the back is reduced to 83 ft. 6 ins. by two insets.

Having completed the cofferdam, the contractors commenced to remove the old masonry, and to excavate the site to a depth of 23 ft. 9 ins., at which level blue clay was indicated on the plans.

When a depth of 18 ft. had been reached no indication of blue clay appeared, and the contractors began to experience some doubt as to the accuracy of the drawings, and consequently as to the advisability of proceeding further with the excavation. Acting under the orders of the responsible engineer, however, they continued operations, with the result that, at a depth of 21 ft. below the bed of the river, water burst in beneath the cofferdam and flooded the foundation.

The suggestion was then made by the representatives of the Council that the cofferdam was of faulty construction, and as this was negatived by the contractors, who believed the plans were incorrect, Messrs. Tilley & Sons were called in by the Council to make trial borings. It was then definitely ascertained that the solid blue London clay only commenced at a depth of 25 ft. below the level indicated on the contract drawings. This startling fact seemed to arouse the officials of the County Council, who then decided to test the sites of the Lambeth abutment and of the intermediate piers. As a result of this tardy investigation other errors were found in the plans, and it was accordingly decided that piles should be driven down to the blue clay to afford adequate support for the concrete foundations.

It will now be seen that the Council had fairly entered upon the series of difficulties which have attended the execution of this ill-conceived scheme from beginning to end. Before the piles could be driven the contractors found that it would be necessary to strengthen the landward sides of the excavation, then in danger of sliding into the river because the timber shores were supported only by soft brown clay, ballast, and mud. Baulks of timber were accordingly placed across the opening and securely anchored back into Vauxhall Bridge Road. A new cofferdam had then to be driven outside the first, and to a level of fully 25 ft. lower, so as to prevent any fresh irruption of the river.

When this work had been completed, the next step was to pump out the enclosure in order that the piling might be driven. The piles were whole baulks of timber, 12 ins. by 12 ins. by 20 ft. long, and were driven 3 ft. apart over the whole site of the abutment.

At the Lambeth abutment a considerable amount of difficult work was occasioned by the diversion and reconstruction of the Effra and Clapham storm-relief sewers situated within the old masonry, but owing to the precautions taken and to the smaller depth of the river no mishap occurred to the cofferdam, and the adoption of foundation piles was not necessary.

We now come to another source of trouble which, curiously enough, was never anticipated by the London County Council. It is a well-known fact that the control of the river is vested in the Thames Conservancy Board, by whom rules are invariably made for protecting the interests of those concerned in navigation when a new bridge is to be constructed or an old one is to be repaired. At the time when the plans were under consideration by the Council an intimation was received from the Thames Conservancy to the effect that three 70-ft. wide openings must be left for navigation throughout the execution of the proposed works. This condition was accepted by the Council and included in the Act authorising the building of the new bridge.

Again, it is common knowledge that the Thames Conservancy is empowered to regulate the manner in which any bridge shall be demolished, and we think it is evident that the County Council ought not to have been ignorant of this fact; and before the contract was finally settled there ought to have been a clear understanding between the two public bodies to whom we refer, but unfortunately it happened that, owing to the absence of any working arrangement, considerable delay and unnecessary cost have been incurred.

The first difficulty was occasioned by the removal of the eight river-piers of the old bridge. When the contractors asked the resident engineer how it was proposed these piers should be removed, they were instructed to blow up the piers by dynamite, and to collect the fragments from the bed of the river. The contractors, however little they may have believed in this method, were compelled to procure supplies of dynamite, but received an intimation from the Thames Conservancy that the quantity delivered was far in excess of the permissible limit. The Council next took up the matter, inquiring of the Thames Conservancy what charges might be used for blasting purposes in the river. As the maximum charge was found to be two ounces, the idea of employing dynamite was definitely abandoned.

The contractors then came to the conclusion that, in order to carry out the work of demolishing the old piers in such a way as to satisfy the requirements of the Thames Conservancy, it would be necessary to build cofferdams round the piers and to remove the masonry piecemeal. For nearly two years the County Council would not allow this course to be followed, contending that it was totally unnecessary. Finally, however, the contractors received the intimation that if they went on with the work in the manner proposed it would be at their own cost. Notwithstanding this warning the cofferdams were duly built, but it was only possible to deal with one pier at a time, owing to the condition of the Thames Conservancy that three 70-ft. openings should be maintained for navigation. It was, of course, too late at that time for any modification of this stipulation, which has been responsible for very considerable delay and additional expense, as ultimately the Council had to pay the contractors for these dams as extras.

As the Council still determined to adhere to the concrete bridge originally contemplated, and also owing to the unstable nature of the river bed, it was thought desirable to drive foundation piles down to the blue clay, in order to afford adequate support for the whole of the river piers. Accordingly the contractors were ordered to provide 3,000 iron-shod piles, for which, as well as for the labour and time occupied in driving them, the Council was prepared to pay. By the time the piles had been supplied, however, the order was countermanded, and the contractors received instructions that the various sites were not to be piled.

Judging by this extraordinary order, it appears that undue confidence must have been placed in the soft, brown clay beneath the river bed; and this opinion is further supported by the fact that the resident engineer instructed the contractors to reduce the length of the cofferdam piles for the centre piers by 10 ft. to 15 ft. These piles, we may explain, had been procured, with the consent of the Council, of extra length for making due provision against further mishap. The contractors protested against the reduction of length, predicting disaster; but the only effect was a still more peremptory order. The piles were reduced in length and driven into the brown clay, with the result that at the Westminster centre pier a serious breach occurred in the cofferdam, which created an unavoidably long delay and much expense. Remedies were suggested by the representative of the County Council of such a character that the contractors refused to adopt them unless ordered to do so by the chief engineer. When these remedies were attempted worse damage was done, and the whole structure was threatened with disaster.

Finally, the contractors succeeded in repairing the cofferdam, and the work of building the pier was duly completed, the contractors being again paid for the additional work as an extra.

Before leaving this amazing series of blunders, we may mention that the County Council at first refused to pay for the damage done to the cofferdam and for the work done by the contractors in reconstructing it in a suitable manner. Ultimately the point was referred for arbitration to Sir Benjamin Baker, who, after a very short inquiry, decided that the Council had been entirely in the wrong.

The next remarkable phase in the history of this bridge is to be found in the

decision made after the appointment of Mr. Fitzmaurice, the present chief engineer to the London County Council, to substitute a light steel superstructure in place of the concrete arches contemplated in the original designs. We have no doubt whatever as to the wisdom of this change, which was rendered necessary, not only by the insecurity of the foundations as designed, but also by the fact that the concrete bridge would not have given the amount of headway required by the Thames Conservancy for river traffic.

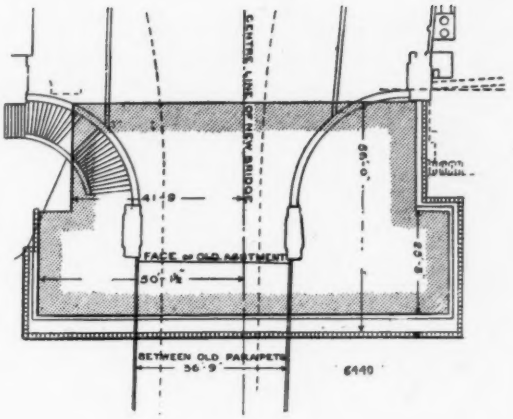


FIG. 1.

Although there is reason for believing that the new bridge, when ultimately completed, will be perfectly safe, yet the fact remains that, for a steel bridge, the number of piers is greatly in excess of that actually required. Navigation of the river will always be impeded to an unnecessary extent, and the new bridge will never be a worthy example of modern engineering design.

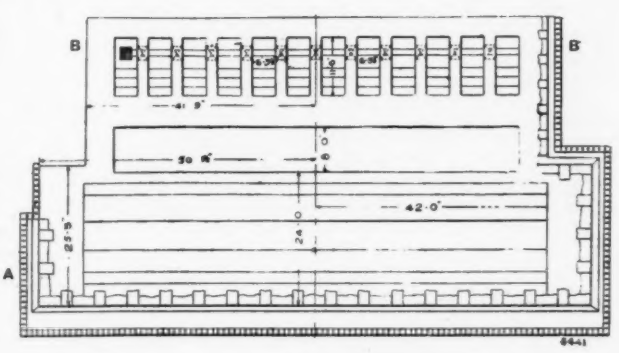


FIG. 2.

It will be seen from Fig. 1 that the Westminster abutment is some 12 ft. in front of the old abutment, thus giving greatly increased accommodation for traffic; and it may here be remarked that the width of the new bridge is 78 ft. between the parapets, as compared with 36 ft. 9 ins. in the case of the old structure.

The general plan of the abutments is shown by Fig. 2. The construction, is more fully shown by the other drawings here reproduced; Fig. 3 is a section on the line *B B*, Fig. 4 is a section at *A A*, and Fig. 5 is a cross section of the abutment.

The body of the abutment is of concrete, and the granite facework of the abutments consists of ashlar masonry laid in Flemish bond in courses of 2 ft. high with 2 ft. headers and 4 ft. stretchers, a batter of one in ten being given to the front wall.

In Figs. 3, 4, and 5 will be observed the gauge-piles, with pointed shoes, forming part of the cofferdam. These piles were first driven at intervals of 5 ft. apart, and the spaces were afterwards filled with other piles having bevelled shoes, the closing pile being wedge-shaped, so as to form a key tightly locking the whole construction. In the section shown by Fig. 3 the concrete is of two distinct qualities; the lower portion, 18 ft. 9 ins. deep, is

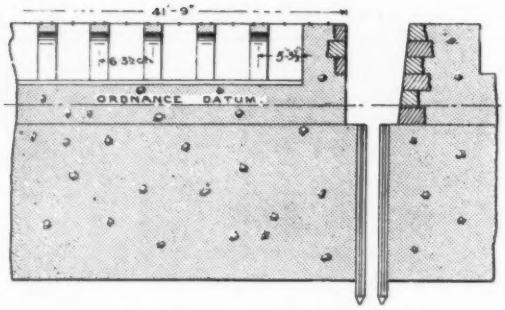


FIG. 3.

FIG. 4.

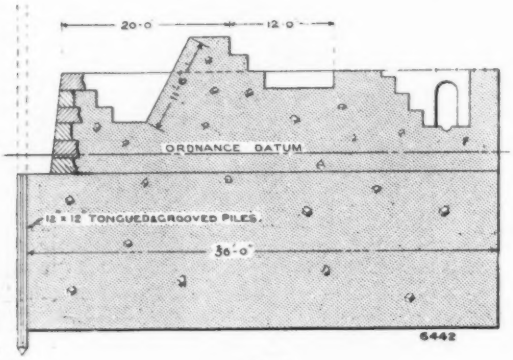


FIG. 5.

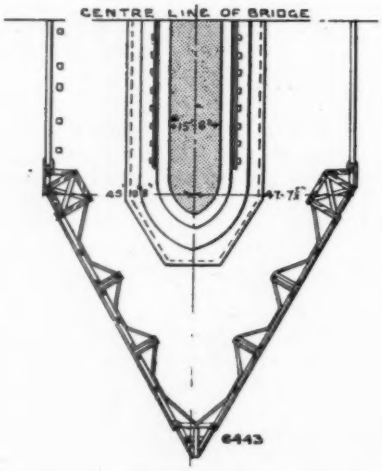


FIG. 6.

mixed in the proportion of 1 : 8, and the upper portion in the proportion of 1 : 6. The cement used in making this concrete was required, after setting for seven days, to withstand a pressure of 400 lbs. per sq. in.; and mortar, mixed in the proportions of 1 part cement to 3 parts sand, was tested at the age of 28 days under a pressure of 200 lbs. per sq. in. It will be seen from the same figure that only three courses of stonework are built along the side elevation of the hinder part of the abutment, in this respect differing from the construction shown in Figs. 4 and 5. Turning to Fig. 5, it will be observed that the face-work in the cross-section there illustrated commences at the distance of 3 ft. from the edge of the concrete, the stones being bonded in with the concrete to depths of 2 ft. 9 ins. and 1 ft. 9 ins. alternately, with the exception of the bottom course, which measures only 2 ft. 6 ins.

We now come to the river piers of the new bridge. Although these and the falsework required for their construction were not quite identical, it will suffice for our present purpose to take as an example the Westminster centre-pier.

Fig. 6 is a section of this pier and a plan of the pier and temporary works. It will be seen that along each side of the pier a floating boom extended to the points where the starlings of the pier commenced, and where the booms were connected to braced-timber buttresses forming the commencement of the timber cutwater, which was built of a series of six timber trusses laid horizontally. The piles used in this work were all 12 ins. by 12 ins. connected with 12 ins. by 6 ins. diagonal walings, lateral support being afforded by sloping trusses, bearing at one end against the inner, and at the

other against the central straining pieces The position of the cofferdam is indicated by the polygonal lines outside the foundation. The principal difference between the protective works for the centre and intermediate piers is to be found in the substitution of 18 ins. by 18 ins. floating booms for the trusses protecting the cut-water of the centre pier, the booms being kept in position and strengthened by three pairs of piles connected by diagonal bracing.

Fig. 7 is a plan of the Westminster centre pier showing the cofferdam in greater detail. The plan is taken at the level of 9·75 ft. above Ordnance datum. The total internal length of the dam was 142 ft. 6 ins., and its width 38 ft. The sides of the dam measure 108 ft. 9 ins., the ends being of polygonal form, as shown in the plan. From end to end of the pier cutwaters the length of the masonry work is 118 ft. 9 ins., the cutwaters being described about equilateral triangles with the radii shown in Fig. 7. One radius is equal to the width of the pier at the top, while the other radii correspond to the horizontal projections of the batter and rake at the bottom of the pier.

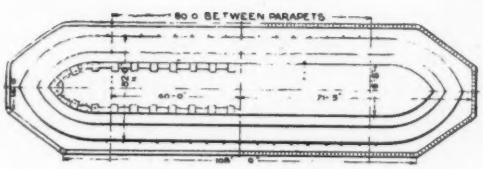


FIG. 7.

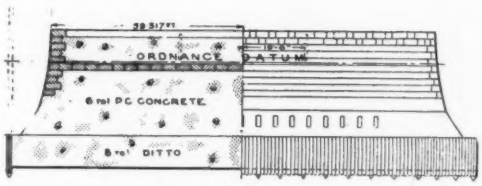


FIG. 8.

FIG. 9.

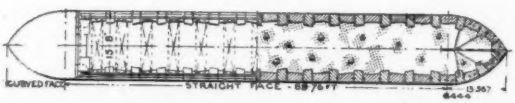


FIG. 10.

The left hand half of Fig. 8 gives a longitudinal section of the same pier, which is seen to consist of one mass of concrete. The centre core in each pier was built of Portland cement concrete, in the proportions of 1 : 6 by weight, deposited in successive layers 2 ft. thick. It may here be mentioned that the masonry shown in the section is of granite in courses 2 ft. deep, corresponding with the depth of the concrete layers, the concrete being brought up in successive layers as each course of masonry was completed.

The whole of the concrete used in the piers was mixed by a simple but effective apparatus designed by the contractors, consisting of a horizontal vessel of segmental form provided with a series of stirring blades on a central shaft. The receptacle has an open top, and can be rotated about the shaft so as to tip out the contents when required, while revolution of the blades still continues. On the occasion of our visit to the works ballast was brought in skips along a tramway ending opposite the hopper of the mixing machine, each skip containing the exact quantity for a batch of concrete, and the necessary volume of cement was measured in a box on the opposite side of the hopper. The materials were tipped into the machine at the proper time, sufficient water being added from a tap fixed in a convenient position. The entire apparatus was erected a little below the level of the decking, so that it could be easily managed and the process observed without trouble. The aggregate used consisted of Thames ballast, and the proportion of water by weight was not more than 10 per cent.

As soon as the concrete was properly mixed it was deposited as quickly as possible and thoroughly rammed until the whole mass was in a gelatinous condition, no ramming being allowed after the concrete had once commenced to set.

The half-elevation of the pier in the right-hand half of Fig. 8 shows the work when brought up to the level demanded in the first contract. Two 6-in. glazed stoneware drain-pipes are provided in each side of the pier. From the top of the work to the level of 14·25 ft. below Ordnance datum, the curved batter of the cutwater nose is struck from the radius of 80·62 ft., and, as shown in the section, the granite face-work commences 4 ft. above the last-mentioned level. The bonding of the face-stones into the concrete is indicated in Fig. 8, and also in Fig. 9, which is a cross-section of the same pier. The exposed face of the granite-work is fine-axed, the horizontal bed-joints being carefully dressed, and the vertical joints finished perfectly straight; but where they come into contact with the concrete the joints are left rough, so as to secure a better bond.

We have now described all the work included in the first contract, and will next proceed to consider those portions of the masonry which are in contract No. 2.

At the present time nothing more has been completed than the work undertaken by Messrs. Pethick Bros., the abutments and the river piers standing at the height of 9·75 ft. above Ordnance datum, while the cofferdams have been cut off at the level of 22·50 ft. below the same level. So far as we are able to judge, the only reason for dividing the contract for the erection of this bridge is to be found in the fact that the London County Council were feeling their way, and we fear that inconvenience and great delay will be experienced by the new contractor in carrying the work above the present level, as observation shows that the mean high-water level at the side of the bridge is some 2 ft. above the existing work. This will necessitate the building of the first course of all the piers during the intervals of the tide, a most unsatisfactory mode of procedure.

Looking at the matter from a perfectly impartial standpoint, it seems a pity that the original contractors were not commissioned to carry the masonry well above high-water level. In fact, as Messrs. Pethick Bros. had on the spot all the necessary tackle, including an aërial rope-way, for the handling of material, they were certainly in a position to build the masonry on much more advantageous terms than any fresh contractor could be.

The masonry still to be erected includes some 10 ft. 6 ins. of solid work in the Westminster and Lambeth abutments, and in all the river piers, as well as the upper courses and the turtle-back caps of the pier cutwaters.

Fig. 9 contains a half-elevation of the unbuilt part of the Westminster centre pier, with the string course and granite plinth. The dotted lines in the plinth at the left-hand side of Fig. 9 indicate the position of the cast-iron panels at each end of the pier, forming a facing for the steel superstructure. The arrangement of the anchor bolts for the skewbacks is as follows: These bolts are of 2-in. diameter, being spaced 6 ft. 5½ ins. centres over the greater part of the half-span and 5 ft. 9 ins. over the remainder, and are to be fixed in pairs 1 ft. 11 ins. apart. They will be carried into the concrete for a depth of 8 ft. 6 ins., and, further, are secured by steel angles 6 ins. by 4 ins. by $\frac{5}{8}$ in., furnished with washers. The holding-down bolts are to be set by template and securely grouted.

Fig. 10 includes a half-plan of the pier at the level of the string course. Here the broken lines indicate the bases of the skewbacks, passing entirely across the pier. Each skewback is a single steel casting, the general form being the same for all four piers, although the dimensions vary somewhat, as the Westminster and Lambeth centre piers are wider than the intermediate piers, and the road-levels are different. The upper surfaces of the granite blocks below the skewbacks are to be dressed so as to leave a $\frac{3}{4}$-in. grouting space to facilitate the accurate bedding of the skewbacks when placed in position.

At the right-hand side of Fig. 10 is a half-plan of the pier just above the present finished level of the masonry. It will be noticed that the vertical joints of the headers and stretchers are provided with grouting-holes, indicated by small black squares in the drawing. Slate dowels, 2 ins. square and 4 ins. long, will be inserted in all stones for a distance of 10 ft. from the points of the cutwaters to the piers. All joints in the granite are to be pointed with granite cement mortar mixed in the proportions of one part granite-sand to one part of neat cement, and no joints are to exceed ½ in., measured on the face. The sand used in mixing the mortar may be either Aberdeen or Devonshire granite-dust, and must be capable of passing through a 900-mesh sieve.

The nose-piece of each cutwater is to be a single stone, and the remaining granite blocks are to be securely dowelled together and connected by iron clamps anchored to the concrete filling, as shown in the drawing. All the headers are to be tied back by 1½-in. round bars, connected with 2-ft. by 2-ft. by ¾-in. anchor-plate bedded in the concrete filling. The headers on the string course are to be at least 3 ft. long, and the string course is to be dowelled throughout its whole length to the course immediately below.

Fig. 11 is a half-front elevation of the Westminster abutment. All the face-work above the springing is to be in ashlar masonry, in courses 1 ft. 6 ins. high. Below the moulded string course, situated immediately beneath the skewbacks, the courses are to be 2 ft. high.

Fig. 12 is a side elevation of the abutment, through which will pass a roadway 18 ft. 6 ins. wide, and a footway 8 ft. wide.

Fig. 13 is a longitudinal section of the abutment, showing the construction of the two arches to which we have just referred. The road arch will pass between two side-walls of brickwork, with a minimum thickness of 1 ft. 6 ins., increased at intervals of 1 ft. 6 ins. by small counterforts of 12 ins. by 9 ins., while a backing of concrete 4 ft. thick will be rammed into the spaces to provide a satisfactory bond for the brickwork. The walls are to be of stock, faced with glazed bricks, and a granite kerb 12 ins. by 18 ins. on each side of the roadway will act as a fender to protect the glazed surface of the walls. The opening for the footway will be in the form of an arched rectangular passage 8 ft. by 8 ft., corresponding with the opening shown on the side elevation of the abutment. The road archway will be turned in a thickness of four brick rings, and will be faced with glazed bricks the same as the side walls.

A portion of the steel joists and plates carrying the roadway of the bridge, and a steel skewback, are shown at the left hand of Fig. 13. The skewback measures 10 ft. along the upper surface, and 5 ft. 6 in. along the back where it abuts against the concrete backing. The face is 4 ft. deep in a plane perpendicular to the thrust of the arch. In Fig. 13 the irregular outline above the datum line indicates the height to which the Westminster abutment has been carried under contract No. 1. Reference to Fig. 5 will make this point perfectly clear.

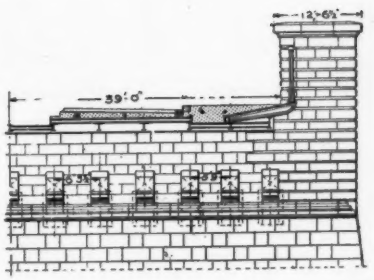


FIG. 11.

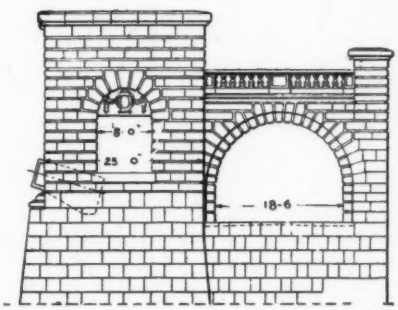


FIG. 12.

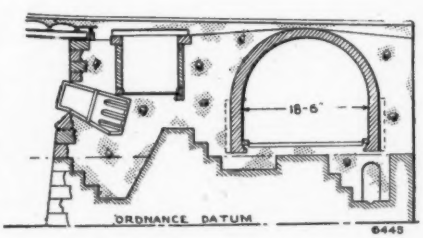


FIG. 13.

Having dealt with the main features of the masonry already built, and that included in the second contract, recently entered into by the County Council, we will refer briefly to the steel superstructure of the new bridge.

Fig. 14 is a general elevation of the bridge, which is to be disposed symmetrically upon each side of the vertical axis passing through the crown of the central arch. The steel arches are to be of the two-hinged type, articulated at the springings and continuous at the crown. The arch ribs will have a depth of 3 ft. 6 in. at the crown, increasing to 4 ft. near the hinges. Consequently, the curves of the intrados and the extrados will not be quite concentric, and it should be observed that the radii differ somewhat in the various spans. The spandrels are to be of the vertical type, having struts spaced to correspond with the radial stiffeners on the main-arch ribs.

Fig. 14 shows the projecting part of the skewbacks and the general design of the hinges. A plan of the bridge is given in Fig. 15, by which it will be seen that the extreme width over all is 82 ft. 8½ ins.; while the width between the

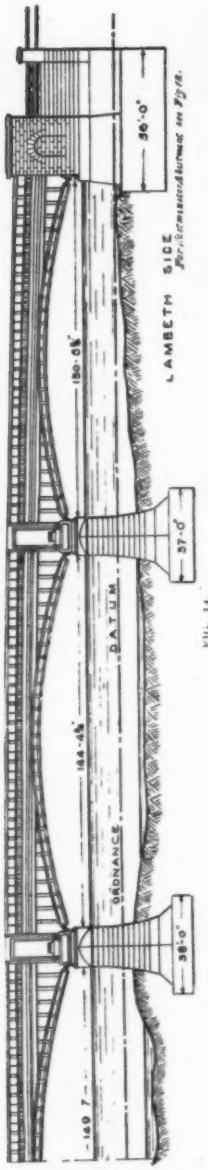


FIG. 14.

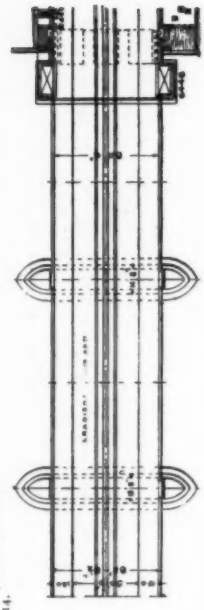


FIG. 15.

parapets is 80 ft., including a roadway 50 ft. wide, and two footways each 15 ft. wide.

On each side of the centre line a space 8 ft. wide will be provided for tramway tracks. Suitable provision is to be made for gas, hydraulic, and drain pipes under both the footways. The gradients proposed are 1 in 39·29 from the Westminster approach, and 1 in 40·75 from the Lambeth approach, the gradient extending in each case to the centre of the intermediate span; and between the latter points the profile of the road surface will be a curve struck with a radius of 75·59 ft. The Westminster approach will be straight on the eastern and curved on the western side, and will terminate at a junction with Grosvenor Road. At the Lambeth end of the bridge the approach will commence with a curve 25 ft. from the face of the abutment and terminate opposite Upper Kennington Lane, at its junction with South Lambeth Road.

The contract for the remaining masonry and the steel superstructure has been awarded by the Council to Mr. C. Wall, of Chelsea, the price being £142,942. Mr. Wall is a builder of the highest repute, and one of his most recent contracts is the construction of the handsome viaduct replacing the old Highgate Archway. There is, therefore, every reason for believing that the contractor is capable of doing full justice to the public and himself in undertaking the masonry work necessary for the completion of Vauxhall Bridge. With regard to his qualifications as a structural engineer and his facilities for the construction of steel arches, we know nothing beyond the statement made at a meeting of the London County Council that he proposed to erect and equip works necessary for the execution of this contract.

It is very difficult to understand the action of the Council in connection with the tenders in respect of the second contract. Thirteen offers in all were received, of which the following five only were considered:—

Messrs. Pethick Brothers	£137,073
Messrs. A. Fasey & Son	£141,741
Mr. C. Wall...	£142,942
The Patent Shaft & Axletree Co. ...	£153,551
Messrs. Heenan & Froude... ...	£154,584

All these tenders provided for the employment of British steel, and we are informed that the firm whose tender is at the head of the list proposed as subcontractors for the steel-work any one of the following firms:—

The Patent Shaft & Axletree Co.
Messrs. A. Handyside & Co.
Sir W. Arrol & Co.

We also understand that the lowest tender was recommended to the favourable consideration of the Bridges Committee by the chief engineer to the County Council, who is amply satisfied with the work already done by Messrs. Pethick Brothers. In reporting to the Council, however, the Bridges Committee passed over all other offers, and recommended for acceptance the tender made by Messrs.

Heenan & Froude, at £17,500 above the amount of the lowest tender. It appears that the Council was unwilling to accept the advice either of its chief engineer or of the Bridges Committee, and determined to adopt the offer made by Mr. Wall, the amount of which, although not so high as that of Messrs. Heenan & Froude, was £5,827 higher than the lowest tender.

Considering the highly satisfactory manner in which Messrs. Pethick have carried out the first contract, and bearing in mind the fact that they also had all the plant and machinery on the site ready for making an immediate commencement with the work, it is an extraordinary thing that their tender was absolutely rejected by the London County Council.

No satisfactory reason has ever been given for the action by which the ratepayers will be called upon to pay a totally unnecessary amount of nearly £6,000, and the whole transaction is distinctly suggestive of the days when the Metropolitan Board of Works held sway over the destinies of London.

The date originally fixed for the completion of the bridge was the year 1903, and it is now announced that the work is to be finished in 1905. If this forecast should be realised the work will have been in hand for the unusually long period of seven years.

Modern Woodworking Machinery.

By M. POWIS BALE, M.Inst.C.E., M.I.Mech.E.

(Continued from page 387.)

IV.

A VAST number of more or less special machines for working wood are in use for the various operations of railway-carriage building, ship building, cooperage machinery, wheelwright's machinery, etc., but exigencies of space prevent me from making more than a small selection.

The greatest novelty, and one of the most ingenious woodworking machines that has been introduced for many years, is the "Marbut" wood carving machine. This machine is especially adapted for producing automatically carved mouldings of a great variety of patterns, which it does by an extremely ingenious arrangement of chisels and cutters. We regret, however, that we are unable to reproduce a photograph of this machine.

A variety of machines are in use for making "wood-wool," or fibre, which is now largely used for packing, etc. These usually consist of a pair of knives—one of which is serrated for scoring the wood, and one is plain for cutting it off—fitted into a reciprocating slide and driven by a crank and connecting-rod. The wood is held by weighted levers and automatically fed forward to the knives, the rate of the feed being varied according to the nature of the wood and the fineness of the fibre required; and the feed is arranged to stop automatically. The machines are sometimes made double- or quadruple-action, and cut both ways of the traverse, where a large output is required; the knives not in action being automatically withdrawn to avoid blunting by the friction of the wood.

A great amount of ingenuity has been expended in devising machines for dovetailing purposes. These may be divided into two classes—(1) those in which circular saws are employed, and (2) those in which cutters are used. Class 1 are especially adapted for heavy packing-case work, and class 2 for drawer and general cabinet work.

In the cutter machines the dovetail is formed either by one or a series of cutters shaped like a dovetail, the wood being usually held by cramps on a compound slide and brought forward to the cutter by means of a lever, suitable stops being employed to regulate the size of the dovetail. Where a series of cutters are used it is important that they are made adjustable, or variation in wear or misfits will be produced.

FIG. 31.

Fig. 31 illustrates an Armstrong's patent dovetailing machine by Messrs. T. Robinson & Son, Ltd., Rochdale. This machine is especially adapted for box and case dovetailing, and its action may be thus briefly described: Two circular saws, or discs, are mounted to run loosely on two short pins; these are inclined to one another at the same angle as the two sides of the dovetail pins. The two saws are geared together by two bevel-toothed rings fitted upon their adjacent faces, and motion is given to them by bevel-gearing working into a bevel-ring fitted to the outer face of one of them. By suitable gearing the inclination of these saw discs can be changed from vertical to horizontal, and arranged to cut the "pins" and "tails" as required. The table carrying the wood is made self-feeding and placed radially to the saws, and the cuts are made at right angles to the wood.

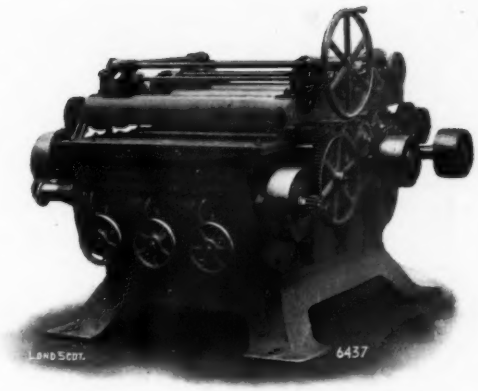


FIG. 32.

Fig. 32 shows a patent three-cylinder sand-papering machine by Messrs. Thos. Robinson & Son, Ltd., Rochdale. This machine is especially adapted for

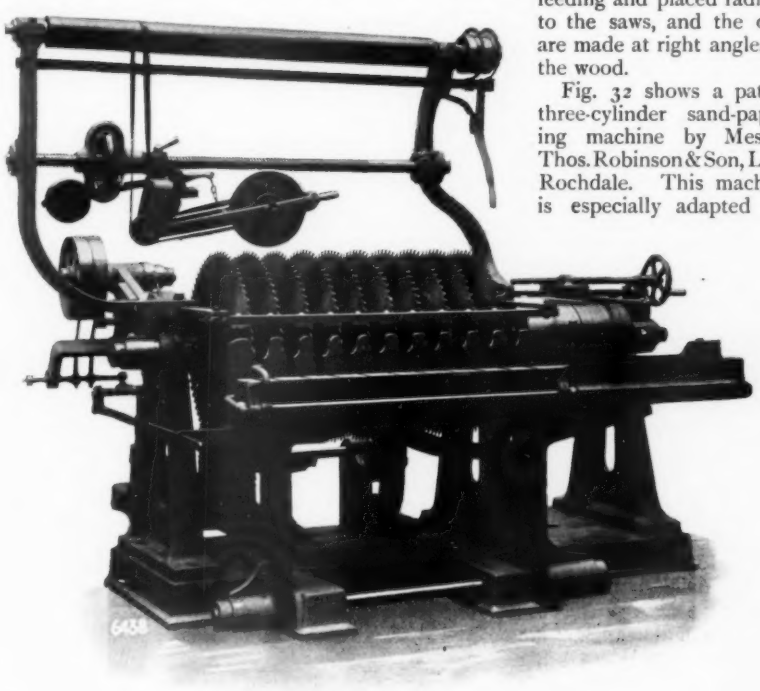


FIG. 32.

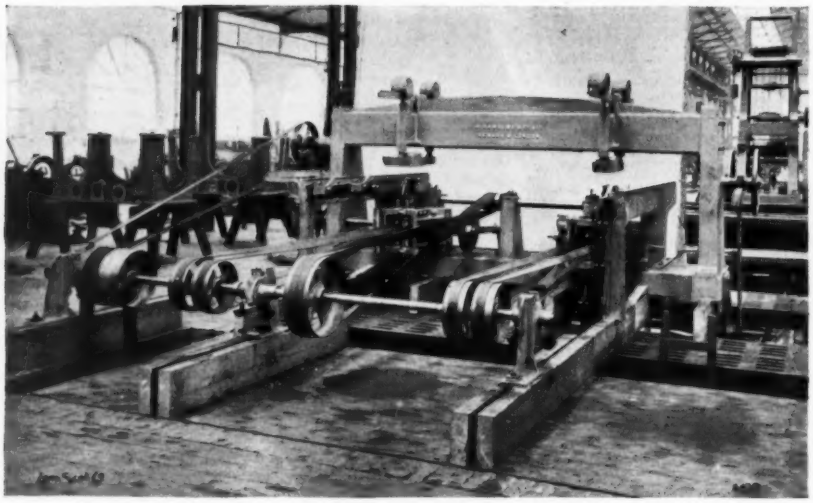


FIG. 34.

smoothing and polishing wood, such as framed doorwork, parquetry, etc. The three cylinders are covered with varying grades of sand paper, and in addition to revolving are made to oscillate by means of a crank motion, and are independently adjustable to any desired cut by turning the hand-wheels shown in the front of the machine. A simple device is used for holding and taking up the stretch of the paper, and an exhaust fan is fitted for carrying away the dust.

Fig. 33 shows an automatic wood-block cross-cutting machine, with multiple circular saws, by Messrs. John Pickles & Son, Hebden Bridge. In this machine the wood to be cross-cut is placed in a trough casting, arranged to swing radially by a power-feed to and from the saws. It is fitted with an adjustable stroke and accelerated return motion; also with an automatic stopping and starting arrangement. An apparatus for sharpening the saws in place is fitted; this is traversed by means of a screw, and the emery-wheel can be set to any desired angle to give any required bevel to the saw-teeth.

Fig. 34 shows an automatic sleeper adzing and boring machine by Messrs. A. Ransome & Co., Ltd., Newark-on-Trent. The operation of this machine is briefly as follows:—The sleeper is placed on the machine and caught by two dogs attached to automatic reciprocating rams, which carry it over the adzing cutters which form the two-rail seatings, and afterwards over the augers which bore the four-spike holes at the same time. The adzing cutters can be set to an angle if desired, so as to give any required cant to the rail. A chief feature in this machine is an automatic arrangement for stopping the advance of the sleepers when they are in the exact position to be bored. The boring is done by raising simultaneously the four augers which bore the holes to the required depth; they then sink below the sleeper, and the dogs being set in motion again, another sleeper is brought forward. The output of this machine is very large.

Works Management and Workshop Practice.

Conducted by JOHN ASHFORD, M.I.Mech.E., and W. H. WILSON.

Workshop Costs.

IT is becoming increasingly necessary, in the present days of slack trade and keen competition, that manufacturers should know exactly what it costs to make their goods; for, without such knowledge, the conducting of business becomes a matter of speculation instead of certainty.

It is an old saying that "fools manufacture while wise men buy and sell," the underlying argument of which is, no doubt, that when an article is bought to sell again its cost is definitely known, and the simple difference between the cost price and the amount obtained from the sale constitutes profit. When manufacturing, it is a case of buying material, labour, shop accommodation, use of machinery, and a number of other items, all of which need to be taken into account before the cost price is known.

In a factory where a large number of men are employed it is far from a simple matter to obtain correct particulars of the labour charges, partly because of the ignorance of the men who have to account for their time, and partly through either wilful or careless misrepresentation. The collection of information as to the cost of production is usually placed in the hands of a clerk, who, with his assistants, constitute the cost department. The money spent upon this department, being non-productive, is looked upon as so much loss to be cut down as low as possible, and the importance of the work to be done is much underrated; consequently, to quote the words of Messrs. Sinclair and Frank Pearn in their recently-published book,* "the work done in this department is usually of a confused and chaotic character, devoid of all finality or practical result."

The successful and accurate costing of work is by no means a simple matter, and it demands that it should be done by men with practical knowledge, upon a method that has been carefully adapted to the needs of the factory. The book on workshop costs already referred to contains full particulars of the method or system that has been developed by its authors at the works of Messrs. Frank Pearn & Co., Ltd., pump manufacturers, Manchester, of which firm they are directors. The information contained in the book is of very great value, embodying, as it does, so much that has been developed by practical experience. The key-note that runs through the whole work is struck in the opening words, thus: "Systemisation, always an important factor in the economical production of engineering work, has become, in the face of present-day competition, an absolute necessity." Would that more of our engineering firms realised that fact, and reduced the whole of their work both in the shops and offices to orderly and economical systemisation.

Speaking of cost-keeping in the introduction of their book, Messrs. Pearn make several statements which are of interest; for instance, the following: "A correct and up-to-date record of moneys expended, of the return in material and labour for that expenditure, and of the margin of profit attained, is an important adjunct in the upholding of any business on a sound commercial basis." Many directors feel concerned as to upholding their business on a *sound commercial basis*, but do they realise what an important factor the cost-keeping department may be in effecting so desirable a result, and when the costing method is unsound do those directors realise what a damning effect it has upon the business? The reviewer knows of large factories where, until quite recently, there was no cost-keeping system at all, and where at present it is so faulty as to be actually misguiding.

The opinion of Messrs. S. and F. Pearn on this matter is clearly shown in the following extract: "Should this record, either from the want of a cost-keeping system or from the employment of a faulty one, be inaccurate or incomplete, then, far from being of assistance and affording guidance, it is misleading and harmful." "It becomes imperative, therefore, that any manufacturer or engineer desirous of progressing or holding his own with his competitors should employ some method of ascertaining *the true cost, both in detail and in bulk*,* of all material and of the operations performed thereon. Such a method, to be of practical utility, must be thorough in its

* "Workshop Costs for Engineers and Manufacturers." Manchester: The Technical Publishing Co., Ltd.

* The italics are the reviewer's.

character, *i.e.*, it must not confine its working to the offices alone, but must *extend them into the workshop, so that the course of material in the shops may be accurately followed** step by step by the cost-keeping department in a systematic and progressive manner."

The authors' opinion of many old methods of costing is clearly shown in the following :—"In many establishments the cost office is a time-honoured institution, only existing by the *apparent* importance of its appalling number of books and sheets, and the overwhelming accumulation of figures these contain." "There may have been some system to begin with, but its effects being of an indifferent nature, those subordinates to whom its control has been relegated ... have become in process of time mere automatons, going through a daily routine of entering and re-entering from sheet to book and book to sheet, without troubling themselves in the slightest degree as to the ultimate usefulness of their work."

The function of a cost department is usually considered to be to keep a record of money expended, and to account for it in some way. The record is generally compiled from information sent to the department from the works, and the accuracy of the record depends upon the correctness of this information, which they usually have no means of checking.

The cost system advocated in the book under review evidently aims at much more than mere recording, for it is shown to be an important factor in works management. Instead of recording what has taken place, it begins at the beginning, and says what is to take place. Instead of being a mouldy, fussy department of books, it is a leading department in the works, closely in touch with or controlled by the works manager. The system embraces the ordering of work from the shops *in detail*, the planning of the procedure of the work through its various operations, the recording of the progress made by the work up to date for the information of the management, the location of disproportionate costs and losses, the safeguarding against irregularities and hiding of faults, in addition to the recording of costs.

To facilitate the work of booking, stores keeping, etc., the parts to be manufactured are identified by a code of symbols, so that the name of a part may be frequently omitted, the symbol being used instead. The code used by Messrs. Frank Pearn & Co., Ltd., is explained, the general idea being that similar parts of different pumps, alike in general construction, are denoted by similar numbers, and the type of pump is indicated by a prefixed letter, thus : "A1 on Sheet 1 is a pump body, A8 the flywheel, A10 the cylinder-cover of a well pump ; while B1, B8, B10 are similar parts of a Manchester pump, as on Sheet 3." Where there are several similar articles of different sizes, the size is indicated by a second number, thus : K1.4 is a circular blank flange pattern 4-in. outside diameter ; K1.4½ is a circular blank flange pattern 4½-in. outside diameter—and so on throughout the series.

The symbols used to denote the parts are also used as pattern numbers ; the pattern-racks bear the marks, and in the stores they appear on the bins ; thus the stock of patterns, castings, and parts can be recorded and kept in order with the greatest accuracy and facility. As the patterns are clearly marked with these symbols they appear also upon the castings, and become of valuable assistance to the workmen in both finding the right casting and in correctly booking their work. Extracting from the book : "It can be easily understood how simple, among other things, is the task of the person who has to check the deliveries of castings from the foundry, and for the workman to give particulars of his labour to the time-clerk, while the universality of nomenclature which this method leads up to is of inestimable value."

Castings of a special nature are given the job number of the engine or machine of which they form parts. For this purpose a special holder is described to carry brass figures to form the number, which the moulder impresses in the mould that it may appear upon the casting. In addition to this, the progressive number of the engine or machine is boldly marked on all castings specially made for it with the aid of rubber figures and analine ink. Forged work does not escape the system of marking, a special steel holder for the figures being used to keep the figures in line and enable the marker to impress them all at once.

Undoubtedly a system of marking all castings and forgings, such as described in the book, is of great value in identifying the work and progressing it through the shops. It helps, too, in gathering together the finished parts in stores ready for the assemblers.

In addition to explaining the method of nomenclature and the registration of patterns and materials, the first part includes nine large sheets illustrative of Messrs. F. Pearn & Co.'s method of registering the pattern numbers to simplify the work of ordering.

Part II. treats of the Recording and

* The italics are the reviewer's.

Analysis of Labour. To insure correct recording of quantity and job number, a job number ticket is issued from the casting stores with the castings, and this ticket remains in the hands of the workman until the work is completed, when the quantities are checked to it. This ticket has its use in securing the correct booking of the work, for "the time-sheets are prepared from the workman's job tickets by time-clerks, so that when the sheets are brought into the office they are clean and legible." Specimens of these time-sheets are illustrated, and the method of making them up, comparing with the time-book, etc., is explained.

The third part is entitled "Manufacture or Repetition Work," and it deals more especially with the preparation of the cost sheets by the cost-clerk; the ordering of material from the iron foundry, brass foundry and smithy; the delivery notes accompanying from the foundry to stores; and the booking of the information acquired upon the cost sheets. It is interesting to observe that the cost sheets are made out at the beginning, before ordering the material, which is done from the cost department, and that they contain a full schedule of parts to complete the pump, and that against each part the programme of operations is put down. This "identifies the wages with material." As the job progresses, at each stage the time is booked as money against the operation; thus, as there is only one entry for each operation, a second booking in error or on work replacing waste is readily detected. To quote from the book: "The detail of operations on the cost sheets prevents the following mischances by causing immediate inquiry from the cost department on receipt of bookings from the shops: the same operation being booked twice; two men booking the same operation; the booking of fictitious operations. Thus a detective-like system is established by this detailed tabulation of material and labour."

As the sheets are schedules of all work to be done, and as they are filled up systematically as the operations are completed, they show upon inspection the progress that has been made and the amount of money spent; thus an estimate can readily be made of the time required to complete the contract.

Various sheets are illustrated that are used for posting and preserving the detailed information; such as stock sheets, a page out of the weight book in which the weights of all standard parts are tabulated, and the stock-taking sheet.

Part IV. cannot be strictly called cost keeping, although indirectly it has to do with it, as it deals with the operation of the finished work stores, and the issue of work to the assemblers. By the methods therein advocated economy undoubtedly results, for it provides that all details shall be collected ready for the erector and then issued to him to assemble. All parts being ready to the erector's hands there is no occasion for delay in carrying out the work. It also reduces to a minimum the work of charging up stock parts to an engine number, as it is done all at once, the cost department being advised of the issue by the stores issue sheet.

The last section of the book explains the modifications for costing contract and special work where the details are not of the usual standard.

Speaking of the book as a whole, it is particularly interesting to works managers, for it goes into important details of workshop organisation, as affected by the judicious operation and use of a complete system of cost-keeping in detail. The arrangement of the book is good, and its value is greatly enhanced by the full-size sheets and folios from various cost-books, etc., which show the columning arrangement and ruling.

The system as described is essentially a sheet-and-book system, and although the method of nomenclature reduces the actual clerical work to a low point, yet there is still a considerable amount of it to do which by modification could be reduced. The general scheme of ordering from the cost department is the right thing, but the subsequent re-writing of information on job tickets, time sheets, lists of parts, etc., leaves room for further improvement. When time sheets are written up in the shops by time clerks in consultation with the men, it is slowly done, and the men's time is partly wasted by the interruption. Moreover, there is room for error, either accidental or deliberate; as the time clerk has to depend upon the man for the accuracy of the information as to time that he receives.

The book is a valuable addition to engineering literature, and it is with pleasure that the reviewer would urge every works-manager who desires to be well posted to become a possessor of this most excellent work. JOHN ASHFORD.

A Modern Machine-Tool Shop.

A DESCRIPTION of a recent visit made to the works of Messrs. Geo. Richards & Co., Broadheath, near Manchester, will convey to our readers some idea of the improvements which are being made in machine tools, and the up-to-date methods of manufacture.

Messrs. Richards & Co., Ltd., commenced as engineers in 1880 at City Road, Manchester. The rapid increase of their business requiring larger premises, new works were erected at Broadheath. The works adjoin the London and North-Western Railway on one side—to which are connected sidings for convenience in transporting iron, steel, coal, etc., for the supply of the works, and for removing finished machinery—while the other side is on the Bridgewater Canal.

In 1896, the business of Tilghman's Patent Sand Blast Co., Ltd., of Sheffield, was amalgamated, both businesses now being carried on at Broadheath, under the same management. Since then, yearly extensions have been made, and, at the present time, the works cover an area of nearly four acres.

The manufacturing departments are: machine tools; air compressors; pulleys and line shaft fittings; sand-blast apparatus; and wood-working machinery.

The fitting and machine shop is 160 ft. long by 160 ft. wide, and the whole of the floor is commanded by travelling cranes, ranging in lifting capacity from 1 to 3 tons. The shop is electrically driven, three motors being used—one 50 b.h.p. driving a group of 16 large planers and radial drills, a 15 b.h.p. motor driving a number of small planers, and a 25 b.h.p. motor driving a group of 50 lathes and small tools. In addition to these three testing motors are used, the largest being 35 b.h.p., employed for testing belt-driven air compressors, and two smaller ones, 8 b.h.p. each, which are portable, and constantly in use testing machine tools. This shop contains over 100 machine tools, and is used in the production of machine tools, air compressors, and wood-working machinery.

Adjoining this building is a heavy erecting shop, 160 ft. long by 54 ft. wide. Two 10-ton electrical cranes run the whole length, and have a span of 36 ft., and there is a 3-ton crane in a similar bay, which has 18 ft. span. Tools up to 30 tons weight are built in this shop, and it is also used for testing large side-planers, boring mills and air compressors. Other machine tools in this shop are a 30 ins. by 12 ft. side planer, 8 ft. boring mill, 4 ft. 6 ins. radial drill, vertical milling-machine, universal boring-machine, large horizontal boring-machine, and 12 gear cutting-machines.

Improvements in Boring Mills.

Here, in course of erection and nearing completion, was an enormous boring-mill, with all the latest improvements and capable of dealing with work 16 ft. in diameter. This is in reality an extension of the 10-ft. mill, the massive uprights being moved backwards by a 2-h.p. motor operating the traversing screws. Similarly a 2-h.p. motor is located on the cross-slide for raising the same. The main driving is effected by a 15-h.p. motor on the left of the machine, a direct and positive drive being maintained by a Renold silent chain. As in the other mills made by these makers, the table is driven by a spur-gear fixed on its periphery, which minimises any tendency to lifting when taking a heavy cut. The large annular bearing under the table is turned and ground to a perfect fit, whilst the special form of "Schiele" curve forming the bearing is provided with perfect lubrication by rotating in a reservoir of oil. But the most recent addition to this machine is the new tool-post, shown opposite. In several makes of boring and turning mills with which we are acquainted the balance chain attached to the tool-post lies athwart the cross-slide. This is objectionable, as it interferes in many instances with the lowering of work upon the machine table. Messrs. Richards, in their ordinary type of mill, have considerably modified this by affixing to each tool-post a separate chain and placing the supporting pulleys on brackets fixed at the outer ends of the cross-slide. Thus a free space is provided between the tool-posts without danger of entanglement. As a result of further development, an addition has been made which entirely dispenses with the use of weights of any kind. This device, which is the invention of Mr. Mathewson, consists of a spring-balancing arrangement which permits the ram to be retained in any convenient position. By a reference to Figs. 1 and 2, which show the holder in front and side elevation, it will be seen that the bottom part is pivoted on the saddle of the cross-slide, the radial portion of the holder being cut as a worm-wheel segment, which engages with the worm attached to the saddle. This permits the holder to be rotated to any desired angle.

The ram is carried in slides within the holder, the two front caps forming an additional bearing-surface. The top part of the holder, which is jointed, terminates in a circular head which contains a coiled spring, a ring-wheel, and an equalising fusee. This arrangement is carried on a central spindle, and a flexible cord from the fusee to the ram sustains the weight of the ram by the adjustment of the coiled spring. The tension of the latter is regulated by a worm which rotates the ring-wheel, keeping the latter in a fixed position.

A valuable addition to these machines is the patent positive-feed motion, shown in

plan, elevation and section, at Fig. 3. It consists of two parallel shafts, enclosed in a casing, which is bolted to the side of the machine.

Spur gears are arranged conewise on the shafts, the apices of the cones being in opposite directions. By reference to the plan at Fig. 3, it will be seen that each gear is brought into mesh by means of an independent pinion. The pinions are arranged on the periphery of a disc which is located within the box, each pinion being brought into position by the rotation of the outside handle. The lever on the left operates a clutch, which brings either bevel into gear with the one shown on the end of the vertical shaft, which imparts motion to the traverse screw of the cross-slide, at the end of which is mounted a three-change system of sliding gears, thus giving twelve changes of feed. The independent pinion to each change obviates the possibility of any two coming in simultaneous contact, and for the convenience of the operator the handle is indexed to each change of feed. The casing is partially filled with oil, thus ensuring the perfect lubrication of every tooth.

Another important factor in the construction of machine tools is the perfect alignment of power-raised cross-slides. This has been met by the laying down of a special machine by Pratt & Whitney for the purpose of cutting square-threaded screws mathematically correct. On this special machine all the principal screws are cut with a precision unattainable on the ordinary screw-cutting lathe.

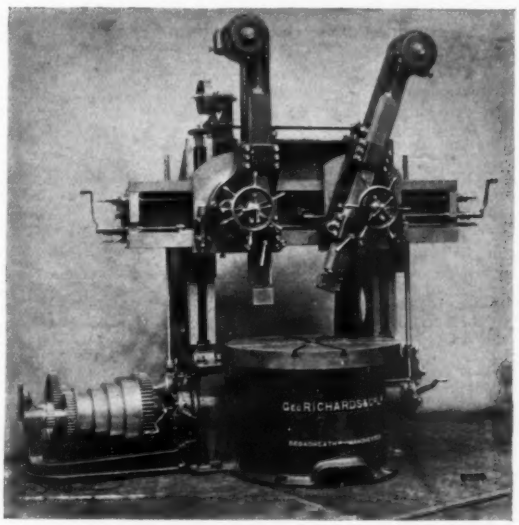
Improvements in Side Planers.

There is also in the heavy erecting shop a special Seller's planer, capable of machining 36 ft. by 14 ins. by 14 ins. This apparently abnormal length of the machine in relation to its vertical and transverse dimensions makes it specially applicable to the machining of side-planer beds. The last-named is one of the specialties of this firm, who, perhaps more than any other tool-makers, have strenuously advocated their utility and economy for particular purposes.

Several of these machines were at work during our visit, most of them performing operations which would have been attended with considerable trouble on the ordinary planer.

In the later designs of this particular machine the double-V'd slide on carriage and bed has been supplanted by a single V on the front of the bed, and a very stiff gib on the under side of the carriage at the back. This, combined with the widening of the carriage, gives a very rigid slide, with an entire absence of lift or any tendency to side-twist.

We recently visited a works in Manchester where several of the side-planers were working at a cutting speed of 20 ft. per minute. As the return stroke is 4 to 1, it demanded, as the manager observed, a sharp look-out on the part of the operator.



MESSRS. GEO RICHARDS' NEW BORING MILL.

Sand-blast Treatment of Castings.

Air-compressors form another important specialty, and are made in various sizes up to 100 h.p., capable of delivering 600 cub. ft. of air per minute at a pressure of 130 lbs. per sq. in. Their application for various purposes is practically unlimited, but they are perhaps more closely identified with the operations of the sand-blast apparatus, which is another distinct line.

The compressors are provided with all the latest improvements, including Mathewson's patent valve, which entirely eliminates the

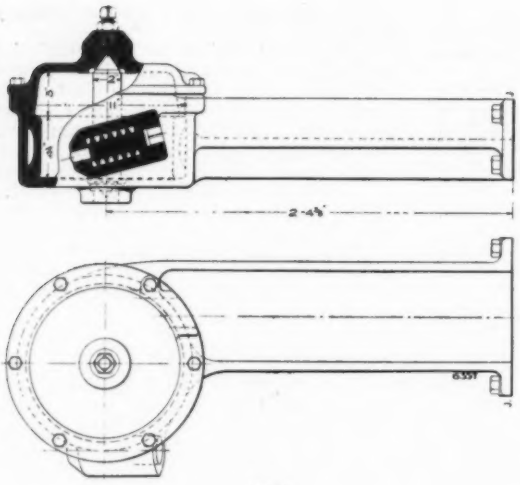


FIG. 2.

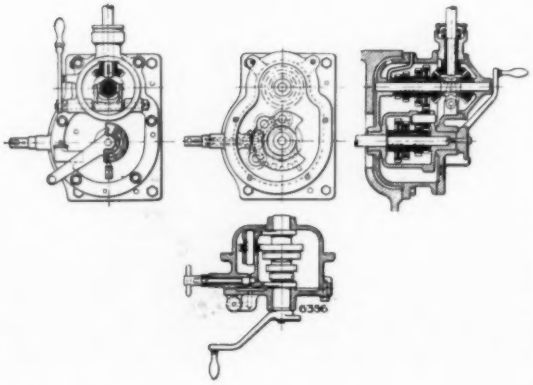


FIG 3.

violent and noisy hammering so frequently associated with the old type of mushroom valve.

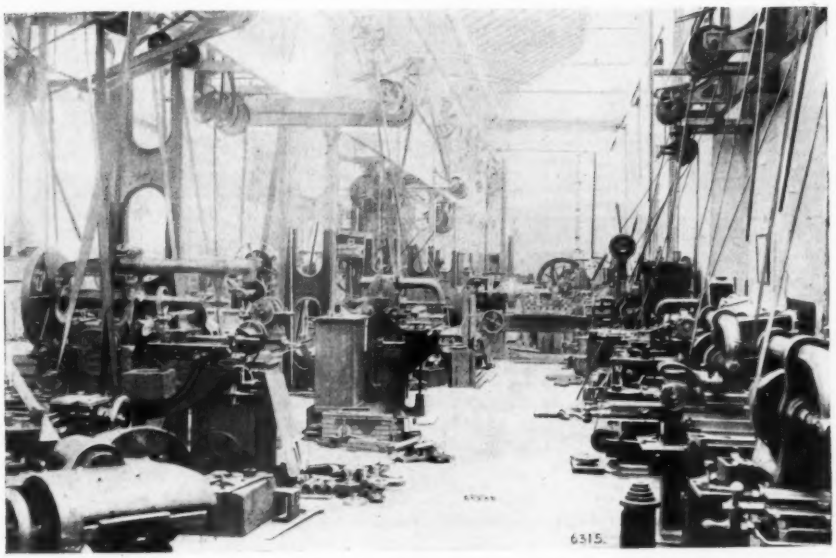
The general utility of the sand-blast, as one of the most effective methods for abrading, is well known, but its use in the engineering shop might be considerably extended. As a method of cleaning castings it is incomparable, and it was most interesting to watch the rapidity with which a rough specimen could be cleared of the adhering sand. A close examination which we made of several castings of somewhat complicated form left no doubt as to its being a valuable accessory to the dressing-shop, the primitive wire scratch-brush being entirely superseded by the sand-jet. By this process 5 tons of ordinary castings, averaging about 20 lbs. each, may be thoroughly cleaned by one man in a couple of hours. In a foundry we know, where the iron-workers are on piece-work, the same quantity of work of a like character would occupy from 10 to 12 hours.

A further application of the apparatus is in evidence in dealing with small castings. These are placed in a "rattler" or tumbling-barrel, into which a jet of sand is discharged. This impinges against the surfaces during rotation, effectually clearing them of all grit without blunting the outlines, which is the natural sequence of the necessarily prolonged tumbling under ordinary conditions. It is particularly adapted for cleaning steel castings, where the removal of outside sand and cores presents extreme difficulty.

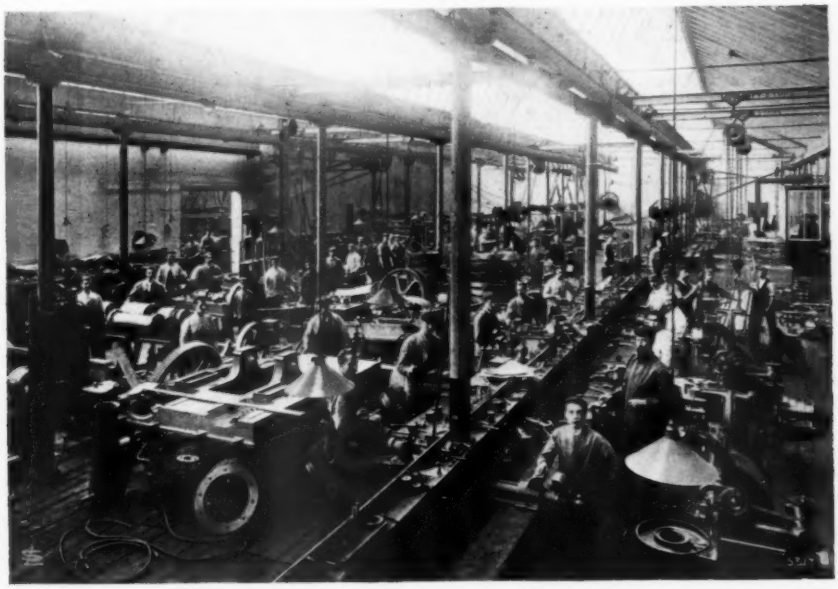
The sand-blast chamber, in which the castings are treated, is situated in the dressing-shop, the apparatus being outside. The inner walls are protected with thick sheet-iron, perforated cast-iron plates form the floor of the chamber, and a pair of folding doors prevent the egress of the dust into the shop. The perforated floor-plates communicate with exhaust pipes, which carry away the whole of the discharged grit. The coarser particles are returned to the apparatus for further use by a cyclone separator, which, by generating a gentle current of air, also drives the finer grains and dust into a movable hopper.

Crossing the main road we entered the works on the opposite side. This building, as shown in plan, contains the pulley-making, sheet-iron working, and pattern shop; also the pattern stores and light foundry, the principal department being that devoted to the construction of pulleys.

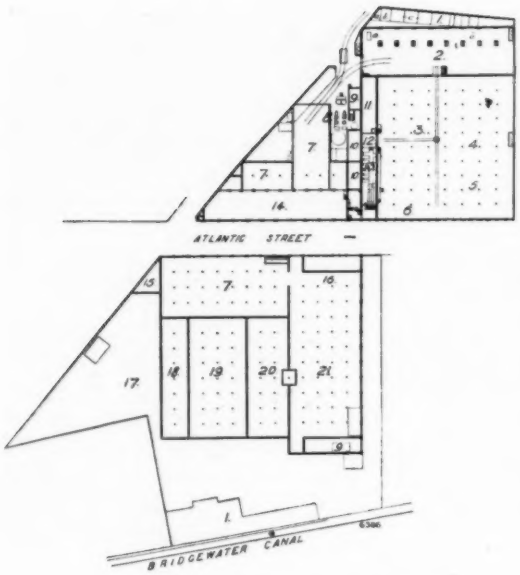
The particular type of pulley, as manufactured by Messrs. Richards, is one with cast-iron arms and wrought-iron or steel rims, which gives a very light and strong form. These



MESSRS. GEO. RICHARDS AND CO.'S WORKS: VIEW IN MILLING DEPARTMENT.



MESSRS. GEO. RICHARDS AND CO.'S WORKS: ERECTING SHOP.



PLAN OF MESSRS. GEO. RICHARDS AND CO.'S WORKS.

1. Stores: (*a*) Turnings, (*b*) Borings, (*c*) Oil and Paint, (*d*) Sand.
2. Heavy Machine and Erecting Shop: (*a*) Gas Engine, (*b*) Milling Department.
3. Fitting and Erecting Departments.
4. Planing Department.
5. Turning Department.
6. Tool Room.
7. Foundry.
8. Gas Plant.
9. Boiler.
10. Gas Engine Room.
11. Stores Room with Steam Engine Room below.
12. Manager.
13. Drawing Office.
14. Air Compressor Department.
15. Core Stove.
16. Blacksmith.
17. Timber Stacks.
18. Pattern Shop.
19. Pattern Stores.
20. Sheet-Iron Shop.
21. Pulley Making Department.

range in size from a 9-in. diam. with a 3-in. face up to 72-in. diam. with a 12-in. face, and are made either whole or split. Main-driving pulleys, from 4 to 16 ft. diam. and of varying widths, are made with wrought-iron arms enclosed in a boss, which is cast round them, the ends of the arms being jagged and dovetailed to ensure perfect security.

In this class of pulley the arms form a double brace from the boss to the rim, the angle or T-ends of the arms rigidly supporting the rim, to which they are firmly riveted. This method of construction gives great support to the sides of the rim, and presents great resistance to the tons of force exerted by the belt.

In the ordinary pulleys with wrought-iron rims and cast-iron arms, as made in the shop, the arms are bored, turned to size, drilled, and riveted on the rim, which has been previously prepared, by rolling, to receive them. They are then turned on the periphery, in special machines provided with double tool-boxes, as evidence of symmetrical construction, only a skimming cut is taken off the rim.

The sand-blast plays an important part in cheapening the cost of the pulleys, all the parts —boss, arms, and rim—being subjected to the operation, with the result that the lightest single-cut over the face is sufficient for finishing.

Running parallel to the pulley shop are three others previously mentioned, the first being the sheet-metal shop. Here the whole of the work is done in connection with the air-compressors and sand-blast apparatus.

The pattern stores, which are commodious and well lighted, are arranged with easily accessible shelves, on which are stored the lighter patterns, those of a heavier type occupying the floor space. The pattern shop, which is particularly well lighted, is also well equipped with modern labour-saving tools, and has ample space for dealing with patterns of large size. Entering the light foundry, we saw dozens of moulds just cooling their contents, representing all sorts of castings of a light kind. Returning to the opposite works, where the heavy foundry is situated, we were informed that considerable alterations were about to be made. Among them was the storage of pig-iron, scrap, etc., on stages, which would be conveyed to the same by an electric hoist. The clearing of the yard will allow of the greater extension of the foundry, which would then be provided with a 10-ton crane. Having looked at some large moulds in different stages of progress, we returned to the drawing office to secure some photographs and take leave of the principal, Mr. Mathewson, who controls one of the most modern and best-equipped works we have visited.

W. H. WILSON.

Reviews of Books.

Iron, Steel, and Other Alloys.—By Henry Marion Howe. (Sauveur & Whiting: Boston, Mass.)

The microscopical examination of metals and alloys is an important adjunct in metallurgical work of to-day, and its results offer much of direct practical value. Starting from the scientific laboratory, the method is gradually extending to the works laboratory, and micrographic analysis is now of considerable value. This value is fully recognised by engineers and metallurgists, but as must necessarily be the case with any science in its infancy, reliable guidance is often inaccessible. The preparation of a work dealing with the present position of metallography serves, then, a very useful purpose, and Professor Howe, in his latest book, has before him an unoccupied field.

Before examining the book, some reference to its dedication is necessary. In metallographic circles Dr. Sorby has long been regarded as the founder of the science, but the author dedicates his book to Professor Tschernoff as "the father of metallography of iron." Naturally, no one wishes to detract anything from the value of Tschernoff's work, but in common justice the fatherhood ought to have been supported by dates. It is interesting to note that Roberts Austen,* whose authority Professor Howe would be the first to recognise, claimed for Sorby the position of pioneer.†

As a whole, the work covers an extensive field, showing in the introductory portion the resemblance of the structure of metals to that of igneous rocks, dealing also with the possible components of an alloy, chemical compounds in metals, solid solutions, and so forth. Cooling curves, freezing-point curves, and the constitution of binary alloys follow. Some eight pages are devoted to a study of the variations in electrical conductivity, and are followed by possibly the most interesting section in the book, that of the metallography of iron and steel. In a section of the work devoted to heat treatment, the hardening and tempering of steel and the chilling and annealing of cast iron are considered. A chapter is devoted to the Phase rule, but its particular application to metallurgy is not clearly shown. A chapter given to the progress in the manufacture of iron and steel between the years 1880 and 1900 has in part appeared in an article by the author in the "Encyclopædia Britannica." The two concluding chapters are respectively devoted to the blast furnace and metallurgical gas furnaces.

The greater portion of the work is written in the first person. Whilst such a style may be permissible in purely subjective matter, or in the publication of personal work, it is in the present case by no means good taste. Further, the book abounds in generalisations, which are often entirely unsupported by experimental evidence. For instance, on page 99 the author proceeds :—

"We shall consider how the rate of freezing and of cooling from the freezing point downward may be expected to influence the degree to which segregation will exist in the cold alloy."

After admitting that this consideration is in the nature of a forecast, it is stated that a series of investigations has been planned to test the conclusions already reached, but these experiments cannot be completed in time for use in the present work. This is not a solitary instance, for many sections of the book teem with conclusions unsupported by experimental evidence.

Prolific as are the opening chapters the chief interest of the work centres in that portion devoted to the metallography of iron and steel. The usually accepted definitions of ferrite and cementite are given, whilst pearlite is described as "æolic" or "quasi-eutectic." The author's reasons for the adoption of the term "æolic" are not convincing; and as an illustration of the terminology employed, a note in the appendix is inserted to say that were it not too late the term "eutectoid" would have replaced that of "æolic" throughout the work. Austenite is described as the characteristic and chief constituent of hardened steel, and is defined as "a solid solution of carbon in iron, the proportion of carbon varying from nothing to 2 per cent."

Martensite, troostite, and sorbite are described as transition forms between austenite on one hand, and ferrite and cementite on the other, probably containing all three of these substances, but in varying proportions. Many metallurgists will not accept the author's definition of martensite as a "transition product"; whilst others would have preferred a practical demonstration to accompany the statement that all hardened steels consist essentially of austenite.

* "Introduction to the Study of Metallurgy." See also "The Nomenclature of Metallography," Iron and Steel Institute, May, 1902.

† Sorby's first paper appeared in 1864.

In stating that instruments such as razors and lancets are tempered to a less degree than tools which, whilst carrying a cutting-edge, have also to offer some resistance to shock, the author is quite correct; but the essential difference in composition is again ignored. In actual practice no engineer would think of making a cold chisel from razor steel; and, *vice versâ*, no maker of razors or lancets would fashion these from chisel steel.

The following quotations serve as a summary of this section of the book:—

"As the pearlite and graphito-pearlite series increase in hardness and brittleness as their combined carbon increases, so does the austenite series as its carbon increases." (Page 191.)

"In short, the hardening power, whether measured by the hardness or by the brittleness induced, increases with the carbon content." (Page 192.)

"That iron becomes stronger, harder, and less ductile as its carbon content increases, must be in very great part referred to the mechanical influence of the cementite which that carbon forms; . . . but it may also be due to the brake action of this carbon inducing part of the free iron to remain during its cooling . . . in one of its harder and stronger allotropic states, beta or gamma." (Page 216.)

Notwithstanding the extent of the treatment and the effusive character of the terminology, the author has extended his domain no further than that of carbon control; control familiar to all engineers, and which in the past, no less than to-day, has dominated every ounce of steel, other than certain special alloys, commercially made.

Turning from the steels to the cast irons, it is stated on page 208:—

"Of the carbon present in cast iron a variable amount turns into graphite during cooling, the proportion increasing with the slowness of the cooling, and with the silicon content of the metal, at least until this latter reaches 0·75 per cent."

In confirmation of this latter statement the reader is referred to a paper of the author's before the American Institute of Mining Engineers in 1900. The following quotations are worthy of careful note:

"It is a familiar fact that the presence of silicon favours the formation of graphite."—(Page 208.)

"The rôle of silicon is not yet clearly established, though Tiemann's[1] as well as Royster's[2] indicate that it has a direct stimulating effect on the formation of graphite."—(Page 210.)

The dates of both Tiemann's and Royster's work are given in the footnote, and it will be noticed that these and the author's paper are all comparatively recent. It is, however, common knowledge to even elementary students that the influence of silicon on cast iron had been worked out long before the appearance of these three papers. Thus on page 131 of Percy's classical treatise[3] it is shown that Sefström observed the influence of silicon in precipitating carbon in the graphitic condition. In 1870 this observation was confirmed by Snelus, and also by Ledebur in 1879. But apart from these early observations, Turner's complete and thorough investigation on "The Influence of Silicon on the Properties of Cast Iron" was published in 1885. This research so completely showed the influence of silicon on the carbon of cast iron that it is taken as a guide in every foundry where mixing by analysis is adopted, and in no country more than that from which Prof. Howe writes. But if the work of Turner, Wood, and Gautier is unfamiliar to the author, surely that of Keep is well known, for this gentleman published his results in 1888, and in the proceedings of the same society containing Prof. Howe's paper of 1900.

Exception must be taken to the description on page 278 of a cast iron containing 2 per cent. combined carbon and 2 per cent. graphite as "typical grey." Such an iron either in the planing machine or lathe would prove anything but typical grey. An ultra-grey cast-iron is described as one containing the whole of its carbon in the graphitic condition. During the cooling of an ultra-grey cast-iron the austenite is stated to be quite carbonless, and instead of the usual reactions taking place, the austenite, owing to its carbonless state, is simply transformed into ferrite (p. 279). A chilled casting owes its properties to the retention of austenite, thus:—

"In this operation (chilling) we probably get highly supersaturated austenite, first by restraining its tendency to resolve itself into graphite and saturated austenite at the eutectic freezing point, and second, by preventing the austenite thus preserved from splitting up into ferrite plus cementite."—(Page 280.)

The process of chilling is treated in an extremely vague manner, and here again the effect of composition is ignored.

Passing to the manufacture of malleable castings:—

"We use a white cast-iron, *i.e.* one which, in solidifying at the usual relatively rapid rate generates within itself only very little graphite. These white cast-iron castings are then annealed by heating them for days to a temperature in region vii. (say 1,000 degs. Cent.), so that the graphite which would have separated sufficiently in slow cooling has a chance to form, and we remove part of this graphite by means of iron oxide in a bed of which these castings are heated."—(Page 281-282.)

The reaction showing the carbon removal is given thus: $Fe_3O_4 + C = CO + 3FeO$; and the following quotation is not without interest:—

"As the carbon at the very skin of the castings is thus removed, that within diffuses outwards to take its place. We may suppose that the actual diffusion is that of carbon in the solid solution or austenite state, and that this diffusion and the change of its carbon from the dissolved to the free state occur side by side, and that it is the free graphite which is directly attacked by the iron oxide."—(Page 282.)

[1] *Metallographist*, Vol. IV, page 319-321.
[2] *Journal of Iron and Steel Institute*, Vol. I. 1897.
[3] Published in 1864.

This ingenious supposition would have carried greater weight had the author stated the manner in which the austenite is converted into free carbon at a temperature at which, according to his own showing, austenite is normal.

Further quotation is unnecessary, and on completing the book the reader is filled with regret that its author has not taken full advantage of the opportunity offered of presenting a clear and concise statement of metallography and its allied subjects. In fine, the book is one long series of brilliant suggestions which, had they been supported by a thorough system of experiment, would have been invaluable to the student of this subject. **P. L.**

The Engineer in South Africa. By Stafford Ransome, M.Inst.C.E. (Archibald Constable & Co., Ltd., London, 1903.) Price *7s. 6d.*

Much of the subject-matter of this book has already appeared in the columns of *The Engineer*, in the form of a series of articles under the title of "South Africa from an Engineer's Point of View." The present volume, however, is something more than a reprint, as some of the original matter has been omitted, and the remainder has been re-arranged and revised. In the earlier chapters we find a consideration of various problems, such as the cost of living and travelling, prospects of employment, the labour question, and the influence of politics upon South African industries. In subsequent chapters the author discusses the engineering industries of South Africa, giving suggestions for their future developments. Among other subjects dealt with in this connection we may particularly mention the theory and practice of the railways. The author shows that in past years the location and management of South African railways were settled almost entirely by political conditions, and that even in the present day railway routes form the subject of considerable controversy between the different colonies. Mr. Ransome strongly urges that an effort should be made to make Johannesburg the centre of the entire railway system, as this city is, to use his own words, "the centre of all things South African." We find an interesting chapter on the harbours of Cape Colony, and another on Durban Harbour, and while the author is quite correct in his statement that very little effort has been made in past years to develop the excellent natural harbours of the country, it seems rather an oversight that he should have omitted all mention of the important harbour works now in progress at Cape Town. If these works were not actually in progress when Mr. Ransome visited South Africa, they had certainly been commenced long before the publication of his book, and we should have thought the careful revision to which he refers in his Introduction might have been extended to this undertaking. There is a good deal of interesting matter in the chapters upon well boring and irrigation, both of which are subjects deserving attention, and the latter is clearly one that will have to be taken up sooner or later by the Governments of the Colonies. The volume is excellently produced, and contains a number of photographic views and a railway map of the country.

Graphical Statics Problems with Diagrams.—By W. M. Baker, M.A., Head Master of the Military and Civil Department at Cheltenham College: (London, Edward Arnold.) Price *2s. 6d.*

This book contains a series of sixty problems which are intended to be solved graphically, directly from the diagrams printed on the same pages. The author states that many of the problems are taken from the Army Entrance Examination papers, by permission of the Controller of His Majesty's Stationery Office. The pages are perforated so that as each problem is solved the sheet can be readily removed. No explanatory matter of any kind is given, consequently the volume is nothing more than an exercise book for the use of students.

NOTES ON LOCOMOTIVE AND RAILWAY ENGINEERING.

By CHARLES S. LAKE.

Locomotives for the Central South African Railways.

THE locomotives in use upon Colonial railways are seldom afforded much attention in the pages of the home press, and it is hoped therefore that the accompanying photographs and particulars of the engines they represent will be of more than usual interest.

The writer has received from Mr. Philip A. Hyde, Chief Locomotive Superintendent to the Central South African Railways, a letter in which that gentleman is kind enough to express his appreciation of these notes, and in which he makes some interesting references to the engines illustrated herewith. Although they are built for the 3-ft. 6-in. gauge, many of their dimensions are fully equal to those of the heaviest standard gauge locomotives in this country; indeed, in a few respects they are considerably in advance of the latter. Dealing first with the larger engine. It will be seen that this is of the 4-6-2-type, with outside cylinders driving the middle pair of coupled wheels. The valves work above the cylinders through the medium of rocking shafts, but the valve-gear itself is not visible, being inside the frames. Extension piston-rods provided with casings are used.

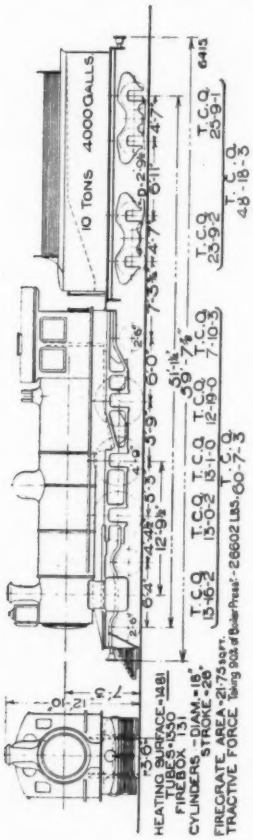
The boiler is of large proportions; and, together with the fire-box, provides 1,481 sq. ft. of heating surface, an unusually large aggregate for a narrow-gauge engine.

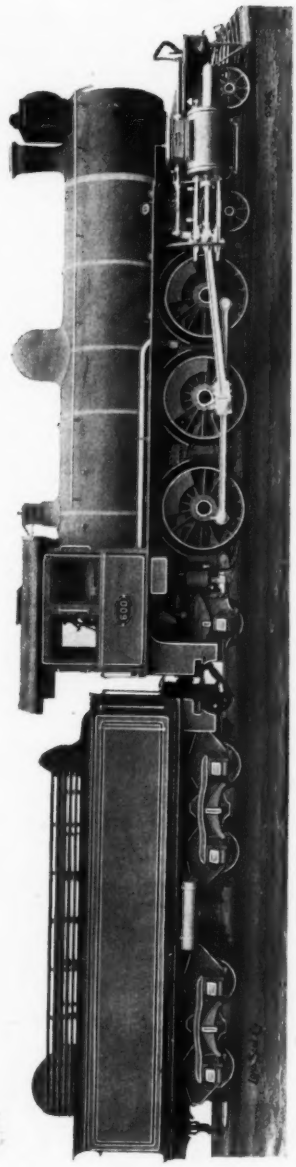
The cab is of commodious design, resembling in outline those one is accustomed to meet with on American locomotives. The engine framing is also in accordance with American practice, being of the bar pattern, made up in this case of two sections spliced together at a point between the centre line of the trailing bogie wheel and that of the leading coupled wheel. The smoke-box, which is of the extended type, is carried upon an independent cast-iron saddle. The tender is very ample in size, having a capacity for no less than 10 tons of coal and 4,000 gals. of water. It is carried upon two four-wheeled bogie trucks and is fitted with high gratings, supported at the ends by transverse plates. The total weight of engine and tender is 119 tons 5 cwts. 6 qrs.

The tank engine is of the 4-6-4-type also, with cylinders and steam chests placed outside the frames. The wheels are similarly arranged as in the previous engines described, except that there is a trailing bogie in place of the carrying axle there employed. The wheel base of the bogie and coupled wheels is also identical in either type. The boilers are of similar dimensions, both having 1,481 sq. ft. of heating surface and a working pressure of 200 lbs. per sq. in. It will be noted that the tank engine is provided with an electric headlight, and that both it and the 4–6–2 engine are equipped with steam sanding-gear and the vacuum automatic brake. The principal dimensions of both types appear on the diagrams, for which, in addition to the photographs, the writer is indebted to the builders, Messrs. The Vulcan Foundry Co., Ltd., of Newton-le-Willows, Lancashire. The engines are admirably designed and of the best construction, and they reflect the highest credit alike upon designer and builders.

Cylinder Ratios in Compound Locomotives.

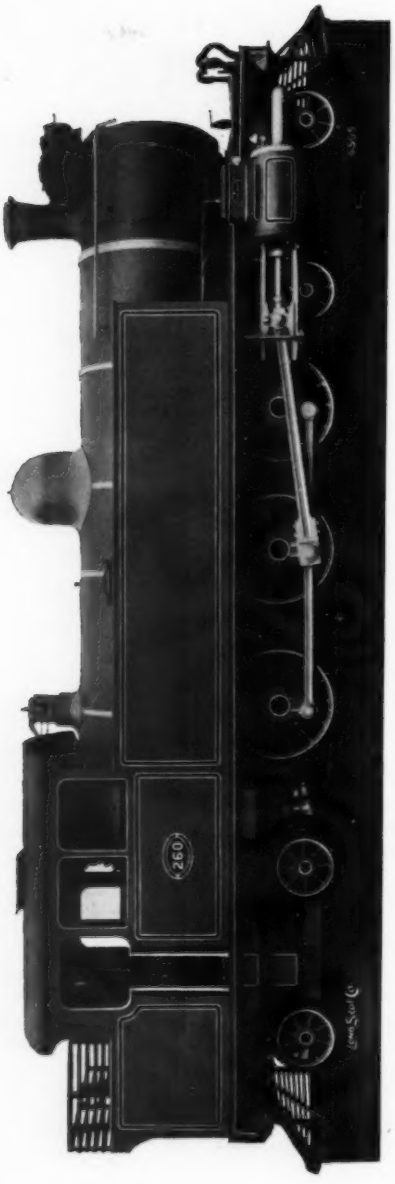
When setting out to design a compound locomotive, the first thing to be considered is the number of cylinders which are to be employed, and that point decided it becomes

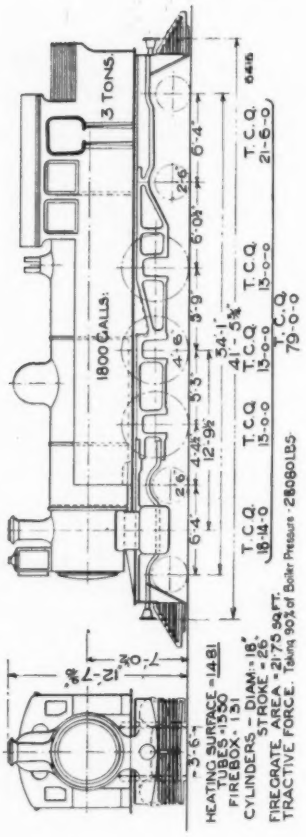

10 TONS
4000 GALLS.
HEATING SURFACE - 1281
TUBES - 150
FIREBOX - 130
CYLINDERS - DIAM. - 18"
STROKE - 26"
FIREGRATE AREA - 21.75 sq.ft.
TRACTIVE FORCE Taking 90% of Boiler Press' - 28602 LBS.



4-6-2-TYPE PASSENGER ENGINE FOR THE CENTRAL SOUTH AFRICAN RAILWAYS.

necessary to determine what ratio to adopt between the high pressure and the low pressure. As regards the first-named point there seems to be little doubt that the two-cylinder compound locomotive is no longer as popular as it was. Three- and four-cylinder engines, on the other hand, are receiving a greater amount of attention at the present time than has ever been accorded to them previously. The fact that simple locomotives still predominate so largely in this country is in no way antagonistic to the feeling which is known to exist in favour of the compound principle being afforded an extended trial on British railways with a view to ascertaining beyond any doubt whether the merits claimed for it by its adherents are outweighed by the disadvantages urged by its opponents. That such





4-6-4-TYPE TANK ENGINE FOR THE CENTRAL SOUTH AFRICAN RAILWAYS.

an investigation will sooner or later be undertaken there seems to be every reason to believe, and indeed the trials at present taking place upon the Great Western Railway are an earnest of what is to follow ; but the instance cited represents only what may be termed the thin end of the wedge, and although the results obtained will undoubtedly provide a valuable clue to the form which future developments will take, they will hardly be accepted as conclusive in view of the wide difference which exists in the design of the competing engines.

The reason for the waning popularity of the two-cylinder compound locomotive is not far to seek, in this country at all events. British designers pay greater attention to appearance than do those of any other country, and the lopsided appearance im-

parted to a locomotive which is provided with a small high-pressure cylinder on one side and a large low-pressure cylinder on the other is quite opposed to their ideas of symmetry; whilst, if the inside position is resorted to, the difficulty of finding sufficient space for the cylinders is immediately met with. Mr. T. W. Worsdell overcame it on the North-Eastern Railway by arranging the cylinders at different levels; but this plan has many drawbacks, and is far from being considered desirable or correct. In spite of all this, however, as good results may be obtained with a two-, as with a three- or four-cylinder engine, from many points of view, and it can also be said for the first-named that it is cheaper to construct. That, however, is not the best way of considering the matter. It may be decided off-hand that a three-cylinder compound locomotive is better than one with only two cylinders, if for no other reason than that with the former the power developed is distributed over three cranks in place of two, and as the three cranks may be arranged at an angle of 120 degs. apart a much better turning effort is assured for the axle than can be realised where only two cranks are employed. There is also another aspect of this matter which has to be taken into account, and that is the method of dividing-up the cylinder capacity.

The two examples of modern practice in which three compound cylinders have been tried—viz., the Webb and Smith systems—are diametrically opposed to one another in this respect, for whereas in the former system the high-pressure area is divided, in the latter the low-pressure is similarly arranged. Mr. Webb employed two 15-in. by 24-in. high-pressure and one 30-in. by 24-in. low-pressure cylinders; whilst the Smith engines have one 19-in. by 26-in. high-pressure cylinder and two 21-in. by 26-in. low-pressure cylinders. There is little practical difference between the two so far as results are concerned. We may take it that the average point of cut-off in the high-pressure cylinders would be the same in each case for identical work, and certainly not less than from 55 to 65 per cent. of the piston-stroke, according to the duty the engine was engaged on at any given time, and that virtually the same area for steam-expansion exists in both instances, so that both may be taken as the approximate equivalent of a simple engine with 19-in. by 26 in. cylinders, or a two-cylinder compound with one 19-in. high-pressure and one 30 or 31-in. low-pressure cylinder; which latter it would be difficult to arrange for the British loading-gauge. A further expedient remains to be tried, and in the writer's opinion it deserves a share of attention. If an ordinary 19-in. by 26-in. outside-cylinder simple engine were to be provided with one 30 or 31-in. cylinder between the frames, and the same principle of working adhered to as with the majority of simple locomotives, viz., by cutting-off at from 18 to 25 per cent. of the stroke, instead of 55 to 60 per cent., as is usual with most compound engines, no more difficulty would be experienced in starting than with the 19-in. by 26-in. engine, which is becoming the standard one on many lines; but where such a locomotive would gain would be in the great economy resulting from the employment of the additional cylinder, which would use up the energy at present wasted in the form of steam ejected into the atmosphere whilst still retaining a large percentage of work value. Such an engine as that suggested would always work compound, and there would be no necessity to resort to simple working when extra power was required. It would retain all the characteristics of a simple locomotive whilst possessing all the advantages of a compound one.

Steam Motor Cars for the Taff Vale Railway.

In accordance with the intimation contained in the Notes for last month, particulars relating to the carriage portion of the above cars are herewith presented, together with detailed drawings illustrating the same.

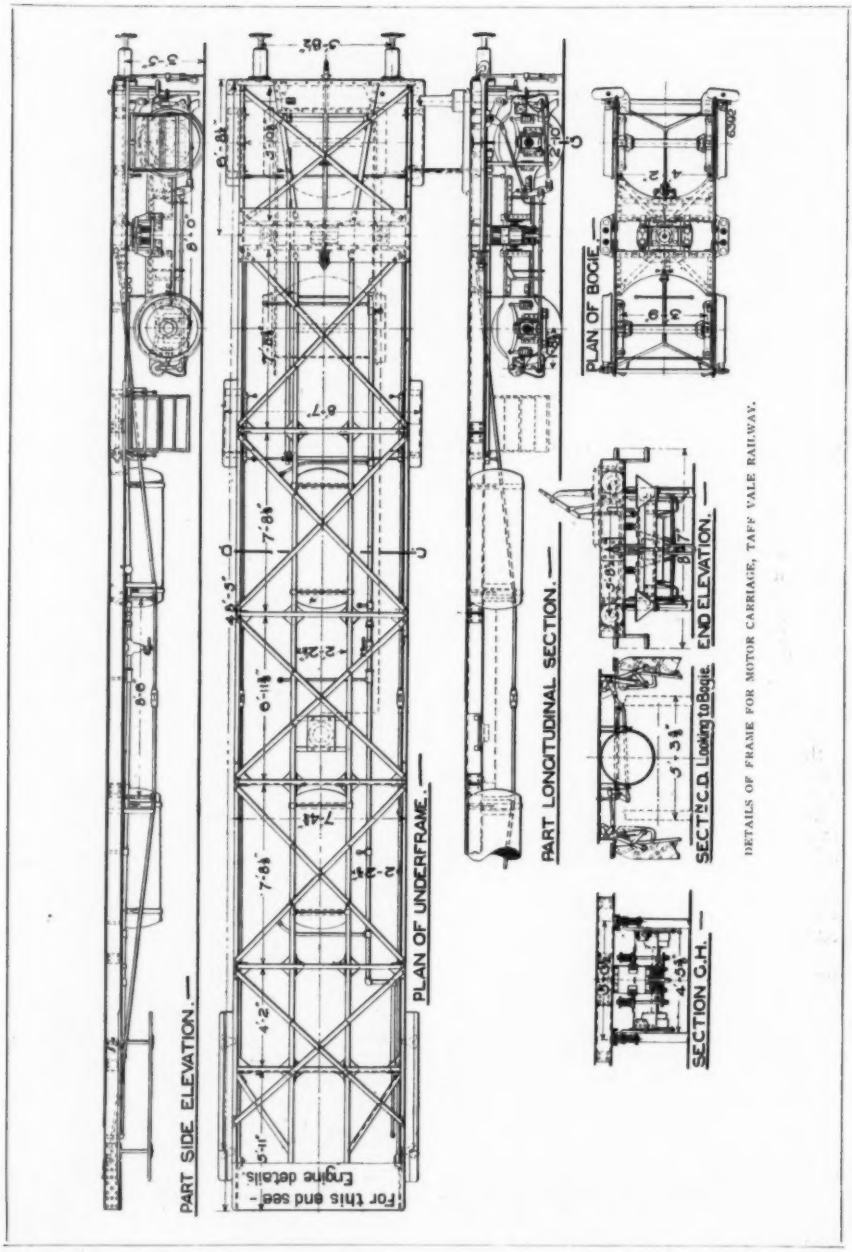
The car is constructed to carry 12 first-class and four third-class passengers; and luggage compartment.

The first-class compartment is furnished with longitudinal seats, upholstered with figured velvet plush, the roof being of lincrusta walton.

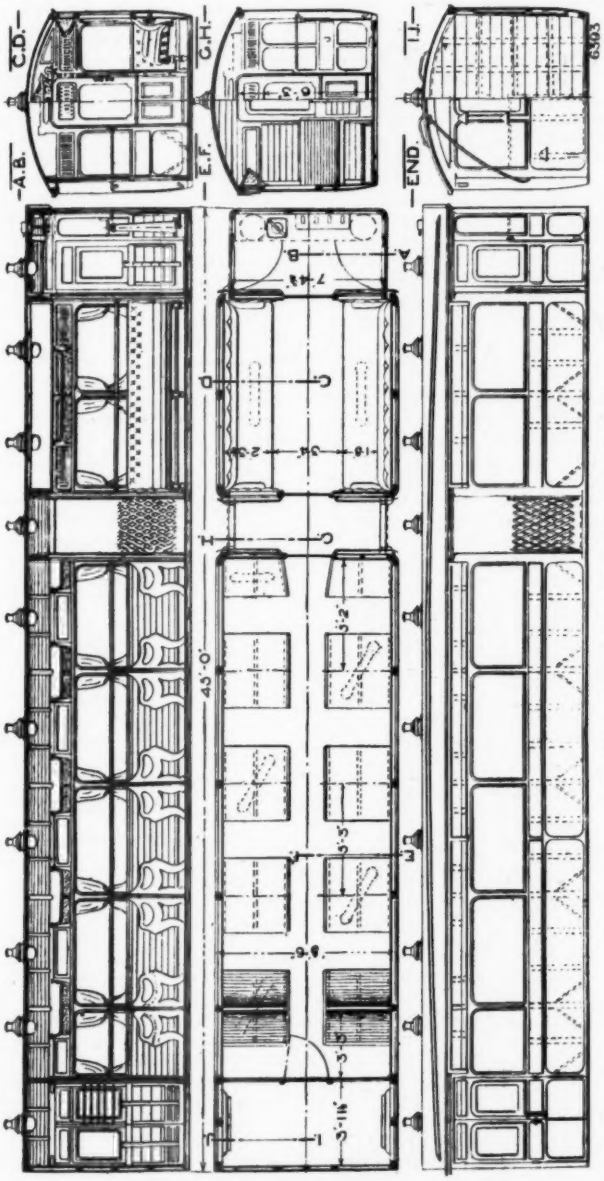
The third-class compartment is furnished with transverse seats arranged in pairs, divided by a central gangway. The seats are constructed of teak frames with oak bars. The roof is of "Bird's Eye" maple veneer, and there are racks for light articles.

Ample ventilation is provided, and both compartments are heated by steam from the engine with warmers of acetate of soda on Peter's system. The lighting is Pintch's system of oil gas.

Entrance to the car is effected by gangways—one at the conductor's end leading to the first-class compartment, and the other at the centre leading both into the first- and third-class compartments. The middle gangway is fitted with collapsible gates, and the end gangway is fitted with doors opening inwards. Each gangway is provided with steps to enable passengers to enter from the



DETAILS OF FRAME FOR MOTOR CARRIAGE, TAFF VALE RAILWAY.



DETAILS OF MOTOR CARRIAGE BODY, TAFF VALE RAILWAY.

road level, and these steps are so arranged that when not in use they are swung back to the width of the ordinary footboard by means of a lever.

The frame of the car is constructed of steel channels and angles, and stiffened by truss rods. Gas reservoirs and heating-pipes for conveying steam to the heaters in the car are fixed under the frame. The car bogie is plate-frame type, with cross-bearers of channel-section steel; laminated bearing-springs are fitted on the top of the axle-boxes, and the ends are attached by hangers in the usual way to the bogie-frame. The body and frames of the car are suspended to the bogie-frame by eight spiral springs, arranged to admit of passing round a 5-chain curve. The wheels are constructed with cast-steel centres cushioned with teak-wood between the tyre and the centre, and secured by a retaining-ring (Kitson's patent).

The cost of working the car is 6*d.* per mile, equal to 3·7*d.* per km.

To ensure proper control of the car when the motor is at the rear end, the conductor can communicate with the motor-man by means of an electric bell, shut off steam and sound the whistle; also apply the hand-brake referred to on the car bogie.

The following are the main dimensions and particulars:—

CAR—	ft.	ins.
Length of body	45	0
Width ,, ,, (outside)	8	6
Length of 3rd-class compartment (inside)	26	1½
,, 1st-class ,, ,,	8	11
Width of gangways	2	8
Height from floor to roof	7	8
Wheel-base of car bogie	8	0
Diameter of wheels, car bogie	2	10

MOTOR-CAR COST PER TRAIN-MILE.

	d.
RUNNING—	
Engine coal	1·36
,, water	·12
,, oil and other stores	·19
,, cleaning	·07
,, steam rising, etc.	·09
,, washing out	·03
Carriage lighting	·12
,, cleaning	·10
,, oil	·01
	2·09
REPAIRS, RENEWALS—	
Engines	·95
Carriages	·51
	1·46
WAGES—	
Engine-men	1·37
Traffic-men	·56
	1·93
Total	5·48

The writer's thanks are due to Mr. T. Hurry Riches for the foregoing particulars, and for the photograph and drawings from which the illustrations have been prepared.

The New L. & N.-W. Railway Express Locomotives.

The new 4-4-0-type express passenger locomotive "Precursor," recently introduced upon the London & North-Western Railway by Mr. Geo. Whale, the Company's chief mechanical engineer, may clearly be accepted as the most advanced example of modern locomotive construction of its kind yet seen. The proportions of the cylinders and wheels are strictly normal, it is true—indeed, those of the former may be described as being somewhat less liberal than one would have expected to find; but on the other hand, this is the first instance of a 4-4-0-type engine provided with over 2,000 sq. ft. of heating surface—indeed, the writer cannot recall any previous design which can show an aggregate of 1,850 sq. ft., whilst the majority of four-wheels coupled passenger engines even of the most modern description fall very far short of the latter total.

In this respect, then, the "Precursor" and other engines built to the same design are unique in British practice, to which latter the writer's remarks are confined. The steam pressure is the same as that finally employed by Mr. Webb on the same railway, viz., 175 lbs. per sq. in., and under all normal conditions this pressure may be considered ample. The writer has not yet had an opportunity of examining detailed drawings of this class of engine, and is therefore not in a position to state precisely how this large aggregate is obtained. The boiler is by no means abnormal, either with regard to its diameter or length, neither is there anything unusual about the size or design of the fire-box. It would appear, therefore, that the large total of 2,009 sq. ft. must be obtained by employing an unusual number of small-diameter tubes, that being the only method by which such an exceptional aggregate could be encompassed within the limitations of a boiler built to these dimensions.

In the matter of cylinder capacity the new engines, as has already been remarked, represent no advance upon recent practice on other railways; indeed, in this respect they bear marked similarity to the latest productions upon the Great Central, Great Northern, and other lines. There certainly seems to be a tendency to restrict the cylinder area of locomotives, whilst augmenting the boiler power, and by this means the advantages of "steam storage," about which we have heard so much of late, are obtained. In the "Precursor" class an adhesion weight of 38 tons is equally distributed over the coupled axles. All things considered, the engines may be taken as representing the best modern practice.

High-Speed Tool Steel.—II.

By J. M. GLEDHILL, Member of Council Iron and Steel Inst.

HAVING described the processes of manufacturing crucible cast-steel, from the casting of the ingot up to the hammering and tilting of the steel into bars, it will now be opportune to touch upon the question of high-speed steel, and its rapid progress and development during the last few years—a development that has revolutionised alike the theories and treatment of tool-steel, as well as its uses in our engineering shops. In proof of this it need only be considered that we have the paradoxical condition that, whereas it was formerly necessary above all things in treating self-hardening steel that every care should be taken not to overheat it—that is, to exceed a temperature of between 1,500 degs. Fahr. and 1,600 degs. Fahr., otherwise its nature and cutting power would be seriously impaired—now it is one of the essential conditions to heat up the high-speed steel very considerably above these temperatures; in fact, to so high a temperature as 2,200 degs. Fahr. or 2,300 degs. Fahr.—that is, a temperature which would practically melt pig-iron.

This is a truly remarkable paradox, and forms one of the most striking phenomena in the recent history of steel treatment.

Partly as a result of this it is now possible, with the "A.W." high-speed steel, to turn and machine steel at a rate up to 400 ft. per min., and also to drill cast-iron at 25 ins. per min.! These are indeed remarkable speeds when it is remembered that only a comparativaly short time back, with the ordinary crucible steels, a cutting speed of 30 ft. to 50 ft. per min. was more like the limit.

It is to Messrs. Taylor and White, of America, that the credit of initiating high-speed cutting is due, and who, some few years back, showed what was then considered to be some remarkable cutting speeds. It will, however, not be denied that the improvement and development beyond their process that have taken place during the past few years are due to our own country; for, whereas in the Taylor-White process their steel could not be sent out in bars, but only in the form of finished tools specially treated on the nose only, now high-speed steel, manufactured in this country, is delivered to users in the ordinary way, and further, its forging and treatment is absolutely simple, in fact, simpler, and is accompanied by less risk, than in the case of ordinary tool steel.

In the case of hardening the point of the tool on the American plan the author can recall a somewhat amusing story. One of such tools was taken and offered for sale to a certain works in the North of England, and the seller was enlarging on its wonderful properties and stating how cheap it was at 3*s.* per lb. The intending purchaser asked, "But how shall we re-forge and re-harden the point of the tool?" "Oh," was the reply, "you will have to send it back to our works when the point is worn off, and we will re-treat the tool and return it to you with another point." "Oh, indeed," said the buyer, "now look here, I do not object to giving you your price for that little bit of the nose-end, but as to the rest of the stuff behind it, well, say 1½*d.* per lb. for that!"

It will, therefore, be seen that the very exceptional treatment required in preparing these tools precluded their adoption and use commercially, and it is a remarkable fact that the English manufacturer is now exporting high-speed steel on a large scale to America.

In forging, annealing, and hardening crucible steels it is essential that the most suitable temperatures should be found for all of these processes, and then accurate means be taken to ensure such temperatures being actually obtained as near as practically possible. This can only be effected by the skilful use of pyrometers or other scientific heat-recorders, for to work on the old-fashioned lines of judging by the eye is no criterion of actual temperature, and is no longer advisable.

It is now known that every composition of steel has its own definite temperature that is best suited for obtaining from it the most satisfactory results, and the nearer this can be worked to the better, any deviation from the correct temperature, up or down, involving a corresponding difference in the efficiency of the steel.

On the question of heat-treatment of steel, it is indeed remarkable what divergent effects different temperatures of heating produce on its molecular structure. To look at a bar of steel lying on the ground, one can scarcely believe that it contains as much mystery and complexity as human nature itself. For example, a bar, if it be heated to a certain degree of temperature, may be left in such a molecular condition as to be considered useless and thrown aside as such. Heated up a little higher, its structure is completely altered, the bar attains a good condition, and is capable of standing great tenacity and ductility. Again, if we take another bar of steel of certain composition, we may heat it to a certain temperature when its molecular structure will be such that it can be cut and shaped into any desired form; but go a step further, and heat this bar to a still higher temperature, and rapidly cool it, its molecular condition has again changed. The bar has become intensely hard, and is capable of cutting softer steels —it has, in fact, become tool-steel. If the steel is heated to a still higher temperature, it is in ordinary phraseology termed burnt; and if you then rapidly cool it, the steel is still hard, but its structure becomes granular, and therefore very brittle. Its tough nature and cutting powers have become impaired; in fact, its molecular structure is again changed.

Having dwelt on the manufacture of crucible steel, it will now be interesting to refer to the use of it, and more particularly with special reference to the use of high-speed steel and of some actual practical work done with it. It has been stated by some that there is not much advantage in its use, but it is easy to prove very greatly to the contrary. There is nothing like facts in proof of statements, and the author does not only give the result of his own firm, but is greatly indebted to many important engineering firms all over the country using high-speed steel for much information as to actual daily practice now existing in their workshops. It is also proved beyond doubt that it is distinctly economical to use high cutting speeds, this being clearly shown in the conclusions arrived at by the Manchester Association of Engineers as a result of an exhaustive series of tests and trials with high-speed tool steel.

Briefly, some of the results arrived at by this committee were that, although more power is naturally required to take off metal at a high speed than at a low speed, the increase of that power is by no means in proportion to the large extra amount of work done by the high-speed cutting. This, one would say, is an important point for all users of steel to bear in mind. Of course it cannot now be denied that machine tools which were fully equal to the cutting power of the old kinds of tool steels are now quite unequal to the capabilities of the high-speed steel—not in driving power alone, but in the absence of rigidity and general strength of working parts for obtaining the utmost work that the high-speed steel is capable of performing. Purchasers of machine tools will doubtless, in obtaining new designs, note this, so that machines and tool steels which are going to be used in them should be, so to speak, approximately equated. Want of power and strength is undoubtedly being realised, and rapid strides are being made by the leading toolmakers to bring their designs into line with the steel.

A proof of this might here be given: We had at our works an ordinary 12-in. lathe, turning armour-plate bolts of from 4 ins. to 5 ins. diameter, and we thought we did wonderfully well in turning them at a cutting-speed of 80 ft. per min. We found the tool at the end of the day's work to be practically as good as at the commencement, and this caused an increase of speed to be suggested.

It was found, however, that the lathe had not sufficient power to admit of any increase of speed, and yet it was felt beyond doubt that if we could only get

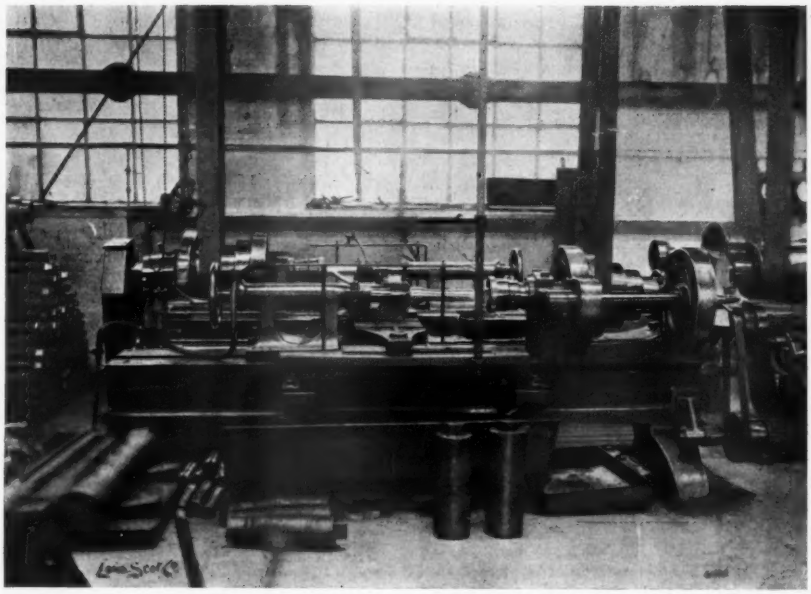


FIG. 5.—OLD LATHE FOR TURNING ARMOUR-PLATE BOLTS.

FIG. 6.—NEW LATHE FOR TURNING ARMOUR-PLATE BOLTS. ONE DAY'S WORK IS SHOWN, VIZ. :—
FORTY BOLTS REPRESENTING THE REMOVAL OF 2,480 LBS. OF METAL.

the required power we could run at double the cutting-speed.

We therefore designed a special lathe with an increased width of belt, from 4 ins. to 7½ ins. width, and an increase of the belt velocity of 400 ft. per min. The lathe was duly put to work, and we immediately began to cut at a speed of 152 ft. per min., the same depth of cut and feed being maintained as when we were cutting at 80 ft. per min., whilst the tool, which is 1¼ in. sq. in section, lasts from 7 hrs. to 8 hrs. without requiring to be reground. So much, then, for bringing up our machines to the limit of power of the steels. Fig. 5 shows the lathe with its 4-in. belt, and Fig. 6 the now existing lathe on which these splendid results are being obtained. One day's work is also shown by the side of the latter lathe. It will be seen that the plain-rolled bar in the back is shown and the number of bolts made from such pieces in a period of 10 hrs. by a 1¼-in. sq. tool.

The bolts machined in this time are 40 in number, as against a production of only 8 when using ordinary self-hardening steel. The following are the actual cutting speeds and feeds on these bolts: Cutting-speed, 152 ft. per min.; depth of cut, ¾ in. Feed, 32 cuts per min. Actual metal removed, 62 lbs. per bolt, or 2,480 lbs. in the day of 10 hrs.

Many other examples might be given of our own practice and that of the great Elswick Works, which are using high-speed steel on a very extensive scale, but it will suffice to annex one or two standard examples, and then to give in the attached appendix what is being done in independent establishments.

Turning a cast-iron flywheel, 12 ft. diameter, 12 ins. face: cutting-speed, 35 ft.; depth of cut, ¾ in.; feeds, 4 cuts per in. (This wheel had barring holes in the centre, about 8-in. pitch.) Ordinary self-hardening steel refused to start on this job at the speed, after which an "A.W." tool was applied and finished the wheel. In addition to using high-speed steel for turning, planing, slotting, and boring tools, it can also be most advantageously used for milling cutters, twist-drills, taps and screwing dies, reamers, wire-drawing, tube expanding, etc. Correspondingly increased speeds can also be obtained with high-speed steel when turning hard materials like chrome-steel for projectiles, old railway wheel tyres, hard cast-iron, etc.

A subject that must be of the greatest importance to all engineers is that of milling, as by the use of this method of working a much greater output of production can often be obtained. By the use of cutters made of high-speed steel still greater economies are effected, for not only can higher cutting-speeds be used than when using ordinary carbon-steel cutters, but the cutters made from the former can be run for much longer periods without being ground, and as the grinding of milling and similar cutters is a comparatively costly operation, a further economy is thus effected.

In support of these statements a few results may be submitted. A pair of straddle-mills, 7 ins. diameter and 1½ in. wide, made of "A. W." steel were used to cut a ⊥-section from bars of forged-steel 7 ft. 3 ins. in length, each cutter taking a cut 1½ in. deep and $\frac{9}{16}$ in. wide, at a feed of 1⅛ in. per minute, the cutting-feed being 75·5 ft. per minute. After milling 18 of these bars—a total length of 130·5 lineal feet, and cutting continuously for 23 hrs. and removing 380 lbs. each, the cutters were quite uninjured; also, the screw-threads on the armour-plate bolts previously referred to are milled at a cutting-speed of 330 ft. per minute, with a feed of 15 ins. per minute.

Another record, but of a rather different character may also be mentioned.

The cutters in question were 4 ins. diameter and 2 ins. wide, and were employed on surfacing work in crucible cast-steel, taking a cut $\frac{1}{32}$ in. deep at a feed of 1½ in. per minute, the cutting-speed being 90 ft. per minute. These cutters have cut continuously for 60 hrs. without being reground, whereas, when using cutters made of ordinary crucible steel at a slower speed, it was necessary to grind them every six hours.

An "A.W." cutter, 5½ ins. diameter and 1⅛ in. wide, cut several lengths of a cast-iron block 12 ins. long, the cutting-speed

being 174·5 ft. per minute, cut ⅛ in. deep, with a feed of 16 ins. per minute; whilst the same cutter, without being reground, took a finishing cut at 357 ft. per minute, and feeding 30 ins. per minute.

A development of high-speed work, which was not at first looked for, has been in the manufacture and use of twist-drills. Many attempts have been made to produce twist-drills from ordinary self-hardening steel with usually very indifferent success. Now, however, twist-drills made of high-speed steel are a practical success, and are largely in use. To those who are not acquainted with the working of these drills, the results obtained from them will be interesting.

An "A.W." twist-drill of 1-in. diameter, working on steel plates of 2-in. thickness at 250 revolutions per minute, and 5-in. feed per minute, generally drills 150 holes without regrinding.

The following is a comparison between a high-speed drill and an ordinary twist-drill. Drilling on gun-cradles of 5-in. thickness, an ordinary American twist-drill did eight holes only and failed, the end being completely burnt up, whilst a high-speed drill did 124 holes at the same speed and feed without suffering any injury whatever. The drills were 2-in. diameter, running at 80 revolutions per minute, and each hole was drilled in 6 mins.

The high-speed drills are equally efficient when used on cast-iron, performing two to three times the work accomplished by ordinary twist-drills, as, for instance, at the works of Messrs. Alfred Herbert, Ltd., Coventry, a high-speed twist-drill of 1-in. diameter drilled 30 holes through a 3-in. cast-iron block, each hole being drilled at the rate of 7¼-in. feed per minute, the drill being uninjured.

The finishing qualities of high-speed steel have also been a matter of some contention, but there is abundant evidence that it will cut at high speeds and yet give a splendid finish at the same time. In support of this the author may refer to a visit recently paid to the works of the above company, and the finish obtained at high-cutting speeds there seen was a revelation. The most excellent finish possible is obtained by them in their very ingeniously designed machinery and when taking one cut only.

It will be instructive to give some further results of actual daily workshop practice, which have been supplied by various firms. These figures are of particular interest, inasmuch as they remove all possible doubt as to the advantages obtained with high cutting-speeds.

In several cases it will be observed that machines are over-matched by the powers of the steel, and it is evident that with machines designed to balance the high speeds a greater output of work would be ensured.

Results obtained with High-speed Steel.

1. Messrs. Alfred Herbert, Ltd.

Rough Turning Mild-steel Bars on No. 5 Hexagon Turret Lathe. Bars 4½ ins. diameter. Turning 31½ ft. per minute. Depth of cut, ¼ in. Feed, ¼ in.

The above is the result of a test. In actual practice higher cutting-speeds and finer feeds are used, as the bar is not supported and will not stand these very heavy cuts when projecting very far from the chuck. The tool was lubricated with a liberal supply of lard oil.

Rough Turning Capstan Lathe Spindles on 12-in. lathe. Cutting-speed, 58 ft. per min. Depth of cut, ⅜ in. Feed, 16 cuts per in.

The above spindles were made of steel containing ·5 per cent. carbon. The tool was lubricated with a liberal supply of suds. The limit of the work in this case was the lathe and not the tool. At another test the same work was done at 63 ft. per min. Cut, ⅜ in. deep. Feed, 32 cuts per in.

Boring Lathe Spindles out of the solid bar with flat cutter. The material from which these spindles are made contains ·5 per cent. carbon. Diameter of holes, $3\frac{3}{16}$ ins. Bored out of the solid at 64 turns per min. = 60 ft. per min. Feed, 85 cuts per in., 45 ins. travel per hr.

Pulley Turning.—Roughing-out 60 ft. per min, Cuts, $\frac{5}{32}$ in. deep. Feed, $\frac{3}{32}$ in. per in. Finishing-cut, 100 ft. per min. Cut, $\frac{1}{32}$ in. deep. Feed, 36 cuts per in.

The pulleys in question are very thin, and will not stand a heavy cut.

Milling Medium Cast-iron with face-milling cutter 4½ ins. diameter, with 14 inserted teeth, cutting at 70·7 ft. per min. Depth of cut, $\frac{5}{32}$ in. Width of cut, 3 ins. Feed, 8½ ins. per min.

Cylindrical Cutter Milling Mild Steel.—Cutter, 2¾ ins. diameter, 21 teeth, running at 72 ft. per min. Depth of cut, $\frac{5}{32}$ in. Width of cut, 3 ins. Feed, 7½ ins. per min.

Gear Cutting, 5-pitch.—Stocking cutter, 3½ ins. diameter, cutting cast-iron spur-gear from solid.

Cutting speed, 75 ft. per min. Feed, 14 ins. per min.

At the time the observation was made 2,580 teeth, 2¼ ins. long, had been cut. The cutter appeared to be in as good condition as after cutting the first 100 teeth (7 hrs. nearly).

2. The British Westinghouse Company, Trafford Park.

Reducing a 1¾-in. Reeled Steel Bar, about ·1 per cent. carbon, from 1⅝ in. diameter to ¾ in. diameter. —Cut: speed, 38 ft. per min. Feed, 100 revolutions per 1 in. of feed. Tool, roughing, ½-in. by 1-in. section.

The tool lasted for over 46 hrs. before regrinding was required.

Boring Steel Wiper-Rings for Railway Motors. —Cutting speed, 35 ft. per min. Feed, 40 revolutions per 1 in. This is equivalent to about 1 in. per min., reducing $\frac{5}{16}$ in. to ¼ in. on each side of the hole. Tool ¼-in. by 1½-in. section.

The tool stood for 10 days without regrinding, and was still in good condition.

Milling Tool-Steel.—Cutting speed, 72 ft. per min. Feed, ·03 in., or 2·7 ins. travel per min. Depth of cut, $\frac{5}{16}$ in. Tool: steel angle-cutter, 50–12.

The cutter worked for 3 hrs., and was then in such good condition that the speed was put up to 84 ft. per min, and the feed to ·036 in., or 3·8 ins. travel per min. The cutter then stood for 8½ hrs. before it required regrinding.

Drilling Cast-iron 4 ins. thick.—Revolutions, 360 per min. Feed, 60 revolutions per 1-in. feed. Tool, ¾-in. drill.

One hundred and thirty-seven holes were drilled before the drill required regrinding.

3. Messrs. Richard Hornsby & Sons, Ltd.

Flywheel Lathe: Hard Cast-iron. —Cutting-speed, 45 ft. Cut, $\frac{3}{32}$ in. Feed, ¼ in.

Piston Pin Lathe: Hard Steel.—Cutting-speed, 56 ft. Cut, $\frac{3}{32}$ in. Feed, $\frac{1}{16}$ in.

Planing-Machine: Hard Cast-iron.—Cutting-speed, 40 ft. Cut, ¼ in. Feed, ⅛ in.

Planing Machine: Soft Cast-iron. —Cutting-speed, 40 ft. Cut, $\frac{3}{16}$ in. Feed, ¼ in.

Crank Lathe Shaft. —Cutting-speed, 69 ft. Cut, $\frac{5}{16}$ in. Feed, ⅛ in.

4. Messrs. Mather & Platt, Ltd.

Rough Turning.—Hard cast-iron rolls, 50 ft. per min. Feed, ⅛ in. Depth, $\frac{5}{16}$ in. Roll about 20 ins. diameter by 60 in. long. A tool will last for three or four days without grinding.

Cast-steel.—30 to 40 ft. per min.; Feed varying according to cut.

Mild Steel.—90 ft. per min. Feed, ¼ in. Depth, ¼ in.

Planing.—Cast-iron and steel, 36 ft. per min.

Drilling—Depth, 4 in. per min. up to 1¼ in. diameter: cast-iron, wrought-iron, or cast-steel.

In conclusion, it cannot be denied that the question of high-speed cutting is one of national importance to our country; for if we are to remain successful and retain our position in the engineering world, we must not only possess the best and most modern designs of machine-tools, but we must also produce the best qualities of tool-steel to serve them to their utmost producing capacities, for it matters not how excellent the one may be if the other is a laggard—the one must be the reciprocal of the other as near as practically possible. Given this, we then place ourselves in the most favourable position for the rapid and economical production of our various manufactures, and for best meeting our opponents in the open field of competition. This is why the question is indeed a national one; and it should be our aim to use every effort and skill to develop our machinery and the tool-steel in connection with it to their highest states of efficiency. Speaking for high-speed steel, we must feel that we are only in the early stages of its manufacture and use, and that nothing approaching finality has been arrived at. When the steel-maker looks at the innumerable alloys of whose behaviour and proportions when mixed with steel so much has yet to be learned, and also to the infinite number of combinations and percentages of those alloys with steel, and the corresponding varied results obtained, it is easily seen what a large field of research there is yet to traverse.

Internal Combustion Motors.*

By DUGALD CLERK, M.Inst.C.E.

IT is my privilege to-night rather to point out what remains to be done in the development of internal combustion motors than to describe what has already been done. Nevertheless, it is desirable to say something as to what has been done, in order to appreciate from the past history the probable line of future progress. In the past the work of the physicist, the chemist, the engineer physicist, and the engineer has been fully called upon to enable the existing position to be attained. Much knowledge is now available on multifarious points in connection with the motors, and they are undoubtedly better understood to-day than at any previous time. Many old fallacies have disappeared, although, unfortunately, some new ones have taken their place. Much difference of opinion still exists on physical and chemical points of the highest abstract scientific interest; but all are agreed, so far as practice is concerned, on certain main features. These leading features are: Initial compression of the working fluid, exposure of the flame to the smallest area of cooling surface for the shortest time, and the use of the lowest flame temperatures consistent with high available pressures. In many cases motors deviate somewhat from these understood requirements; generally not from ignorance on the part of the designers, but from some stern practical necessity. Some of these matters, both practical and scientific, will be here discussed.

Development has followed two main lines. First, improvements relating to the motor itself, including changes in the thermodynamic cycle, followed in the treatment of the working fluid and the inflammable gas within the motor by the modification of such details as admission valves, igniting devices, governing devices, and water and air-cooling devices. Starting gear has also been carefully studied, and, both from the thermodynamic and the mechanical point of view, it may be safely said that these motors have attained a great measure of perfection. Secondly, parallel with the improvements relating to the motor itself have proceeded those relating to means of generating the inflammable, gaseous, or vapour fuel intended to operate the motor. These improvements have related to the economical production of ordinary coal gas, to the effective production of producer gas from anthracite, bituminous non-caking coal, coke, and other solid fuels, to the treatment of heavy and light hydro-carbons and alcohol to produce an effective inflammable vapour, and to the purification and collection of blast-furnace gas, coke-oven gas, and natural gas.

With regard to mechanical improvements, four well-marked divisions may be considered:—(1) Motors for town gas; (2) motors for heavy oil; (3) motors for light oil and alcohol; and (4) motors for producer and blast-furnace gas.

[The speaker then referred to a number of diagrams illustrating typical engines included within the four divisions enumerated.]

It is now desirable to consider the question of heat efficiency, because here will be found the main ground where the physicist and chemist can assist the engineer.

Table I. gives heat balance sheets from 1882 to 1900, showing the results obtained by many well-known engineers from different engines tested between these dates. The table shows a steadily increasing efficiency from 1882 to 1900. In Slaby's first test the heat converted into indicated work was only 16 per cent. of the total heat given to the engine, and this has risen to 28 per cent. in 1898 and 1900, as shown by tests of the Crossley and National engines. Higher efficiencies than these are claimed, and it may now be accepted that heat efficiencies of 30 per cent. and slightly over have been really attained by these engines.

The table shows another peculiarity in the numbers indicating the heat rejected in the water circulation. This proportion has been steadily diminishing, and it reaches a minimum in the large Crossley engine tested by Mr. Humphrey, where the heat loss to the water-jacket is only 24·2 per cent. of the whole heat supplied. In 1882 and 1884, the tests of Slaby and Thurston show heat rejected in water circulation as 51 and 52 per cent. The Society of Arts trials show a reduction in one case in the Crossley engine to 43 per cent., and in the Griffin engine to 39 per cent., when the unaccounted-for heat is included. In Humphrey's test of the Crossley engine of 1900, as has been said, the heat loss to the water circulation was 24·2 per cent. In Robinson's test of the

* The Institution of Civil Engineers. Abstract of the "James Forrest" Lecture, 1904.

TABLE I.—HEAT BALANCE SHEET FROM 1882 TO 1900, WITH OTHER PARTICULARS OF ENGINES.

Name of experimenter.	Year.	Dimensions of engine.	Revolutions per minute.	Compression.	Expansion.	$\frac{1}{r}$	E standard air cycle.	Heat proportions.					I.H.P. E	Heating value of gas taken.	Type of engine.
								I.H.P.	Rejected in water circulation.	Rejected in exhaust.	Difference values.	Total.			
		Dia. Stroke. in.													
Slaby	1882	6·75 × 13·7	160	P V1·37	P V1·37	$\frac{1}{2\cdot66}$	0·33	0·16	0·51	0·31	0·02 radiation	1·00	0·48	Lower	Deutz.
Thurston ..	1884	8·5 × 14·0	160	—	—	$\frac{1}{2\cdot66}$	0·33	0·17	0·52	0·155	0·155 conduction and radiation	1·00	0·515	Lower	Crossley.
Society of Arts Trials	1888	9·5 × 18·0	160	P V1·38	P V1·433	$\frac{1}{3\cdot5}$	0·39	0·221	0·432	0·355	—	1·008	0·565	Lower	Crossley.
Society of Arts Trials	1888	9·02 × 14·0	200	P V1·343	P V1·38	$\frac{1}{3\cdot2}$	0·37	0·211	0·352	0·398	0·039 unaccounted for, including rejected in blank air charge	1·00	0·575	Lower	Griffin (6-cycle).
Kennedy ...	1888	7·5 × 15·0	210	—	P V1·386	$\frac{1}{3}$	0·36	0·209	—	—	—	—	0·585	Lower	Beck (6-cycle).
Capper	1892	8·5 × 18·0	160	P V1·388	P V1·574	$\frac{1}{3\cdot4}$	0·39	0·228	0·389	0·405	—	1·022	0·58	Lower	Crossley.
Robinson ...	1898	10·0 × 18·0	170	—	—	$\frac{1}{5\cdot17}$	0·48	0·287	0·33	0·383	—	1·00	0·60	Lower	National.
Humphrey ...	1900	26·0 × 36·0	150	P V1·321	—	$\frac{1}{5}$	0·47	0·278	0·242 in jacket water and exhaust valve	0·48	—	1·00	0·59	Higher	Crossley.
		2 cylinders { A	—	P V1·321	P V1·386										
		2 cylinders { B	—	P V1·419	P V1·494										
Witz	1900	51·2 × 55·13	95	—	—	—	0·55	0·28	0·52	0·20	—	1·00	0·51	Higher	Cockerill.

National engine in 1898 the heat loss was 33 per cent. In only one of the recent engines—the large Cockerill engine, tested by Professor Witz in 1900—does the heat loss remain as high as in 1882. An examination of the heat rejected in the exhaust, on the other hand, shows a tendency to increase. Adding conduction and radiation to the heat rejected in the exhaust, Thurston's figures become identical with Slaby's; and this, compared with later figures, shows an increase from 31 per cent. to practically 40 per cent., and in Humphrey's experiments to 48 per cent. In only one case, Witz's experiment on the Cockerill engine, is this heat loss shown smaller. In these figures, then, we find steadily increasing indicated efficiency, steadily diminishing rejection of heat in water circulation, and steadily increasing rejection of heat in exhaust gases. From this it is evident that although engineers have succeeded in increasing the amount of heat converted into work and diminishing the heat flow through the sides of the cylinder, they have increased the discharge of heat with the exhaust gases.

To understand the reasons for this it is necessary to consider briefly the thermo-dynamics of this subject so far as it is at present understood, in order to see whether further knowledge is required to enable the meaning of the relative losses and gains in these engines to be better appreciated. Although the general thermo-dynamics of the internal-combustion motor may be considered to be broadly understood, yet physical and chemical knowledge of the properties of air and other gases at high temperatures is as yet insufficient to enable the physicist or engineer to formulate a quantitatively accurate standard engine of comparison; that is, to formulate a conceivable engine in which all heat losses by conduction and radiation are suppressed, and where the efficiency is the full efficiency of the particular cycle under the assumed conditions, whether perfect or imperfect.

The present position of the theory of the internal-combustion motor is in the state of that of the steam engine at the time of Watt, before the accurate determination of the properties of steam. As Watt knew of the latent

heat of steam, but did not know all its properties accurately through a considerable range of pressures and temperatures, so engineers now know of a similar absorption or suppression of heat existing in gaseous explosions without knowing accurately its causes or proportions under all the various conditions of practice. It is perhaps in this task of settling the data for an accurate standard engine of comparison that the physicist and chemist can assist the engineer most effectively. So far, by following the broad lines indicated, heat efficiencies have improved from 15 per cent. to 30 per cent.; and, without doubt, further improvement in efficiency will be made, but with present knowledge it would be impossible to say that the next twenty years would carry us from the 30 per cent. efficiency of to-day to, say, a 60 per cent. efficiency. That efficiencies can be increased much further cannot be doubted. This is evident from an examination of the change in efficiency which may be produced under certain conditions in an engine operated by pure air. Such a standard was first proposed by me in a paper read before the Institution in 1882. In that paper it was recognised for the first time that a standard most nearly approximating to practical conditions of that day would give constant efficiency for a given compression volume for all maximum temperatures above the temperature of compression. The standard engine of comparison, which would correspond most closely with to-day's practice, is an air-engine operated between a maximum and minimum volume as follows: Adiabatic compression of air from maximum to minimum volume; addition of heat at minimum volume, raising the temperature from the temperature of compression to the maximum temperature; adiabatic expansion to maximum volume, and discharge of heat at maximum volume.

Assuming constant specific heat of air throughout the temperature range, it can be shown that the efficiency is constant for all maximum temperatures; that is, for all heat additions above the temperature of adiabatic compression. If γ for air be taken as 1·408, then

$$E = 1 - \left(\frac{1}{r}\right)^{0\cdot408}$$

E = efficiency

$$\frac{1}{r} = \frac{\text{minimum volume}}{\text{maximum volume}}$$

Efficiencies calculated from this formula for various values of $\frac{1}{r}$ are shown in Table II. as follows:—

Table II.—Air Standard Efficiencies.

$\frac{1}{r}$	...	E	$\frac{1}{r}$	...	E	$\frac{1}{r}$	...	E
$\frac{1}{2}$	...	0·246	$\frac{1}{4}$	...	0·43	$\frac{1}{10}$	...	0·61
$\frac{1}{3}$	...	0·36	$\frac{1}{5}$	...	0·47	$\frac{1}{20}$	...	0·70
			$\frac{1}{7}$	..	0·55	$\frac{1}{100}$	...	0·85

If, then, the compression space be diminished in our supposed engine, it is seen that the heat efficiency steadily increases from 0·246 at $\frac{1}{2}$ to 0·85 at $\frac{1}{100}$. No engines have been constructed with a compression space so small as one-hundredth of the total volume. Ordinary practice, however, now goes up to one-seventh, and even one-tenth is exceeded in one or two cases. Within practicable limits, then, if air had been the only working fluid, and its properties were as assumed, then efficiency could be improved within the range of one-half to one-seventh compression volume from 0·25 to 0·55. In the older engines, with considerable heat losses, the expansion curve followed $PV^{1\cdot4}$ very closely; and, accordingly, these numbers could be considered as the standard efficiencies, and deduction only made for heat flow through the sides of the cylinder, tending to keep up the expansion line to the adiabatic. It is found, however, that with modern engines having minimum surface exposure and larger dimensions the expansion curve falls more slowly than the apparent adiabatic. In an engine of usual design of large size, the extreme appears to be $PV^{1\cdot2}$. Assuming air to be of constant specific heat, this can only mean that heat is being added during the whole expansion stroke to an extent sufficiently great, not only to make up for the loss through the sides of the cylinder, but to prevent the whole of the work being done at the expense of the initial energy of the working fluid—that is, heat is added during the expansion stroke. In such a case heat is added to the working fluid, not only at minimum volume, but also during the whole expansion. In this case it will be found that the efficiency is not constant for all heat additions above the temperature of compression; and as expansion $PV^{1\cdot2}$ may be taken as an extreme case, I have calculated various cases approximating to those met in practice.

Table III. shows the result of these calculations. The first column shows the efficiencies of standard engine, as in Table II. Column E_1 shows efficiencies of adiabatic compression of air and expansion $PV^{1\cdot2}$, where the maximum temperature is 1,600 degs. and the suction temperature is 0 deg. Cent. Column E_2 deals with the same case, maximum temperature 1,600 degs., suction temperature 100 degs. Column E_3 deals with

maximum temperature 1,000 degs. and suction temperature 0 deg. Column E_4 deals with maximum temperature 1,000 degs., suction temperature 100 degs. The temperatures 1,600 degs. and 1,000 degs. are taken as the extremes used in gas engines for effective work, and 100 degs. is taken as the suction temperature which is ordinarily attained in most gas engines. It will be observed that the efficiencies fall considerably from the standard efficiencies. The greatest fall takes place with the longest expansion. From these numbers it is evident that an air cycle operating so that heat is added as expansion proceeds, in addition to heat added at constant volume, is less efficient than an engine where all the heat is added at constant volume. In the extreme example, the efficiency becomes reduced to 0·76 of the standard efficiency ; that is, it falls from 0·61 to 0·467 ; that is, the effect of adding heat on the expanding stroke in this particular case, by reducing the efficiency from 0·61 to 0·47, makes the high compression pressure due to one-tenth volume of compression, no better theoretically than that due to one-fifth, when no heat additions during the stroke are made. The loss is less serious where the maximum temperature is 1,600 degs. ; and low-suction temperatures favour closer approximation to the standard. The cause of the loss in efficiency becomes evident when the heat additions during expansion under these circumstances are compared with the heat additions made at constant volume.

Table III.—Air Standard Efficiencies with Heat added during Expansion.

$\frac{1}{r}$	Compression $PV^{1\cdot408}$ Expansion $PV^{1\cdot408}$ E	Compression $PV^{1\cdot408}$, Expansion $PV^{1\cdot2}$. E_1 Max. 1600° C. Suction 0° C.	E_2 Max. 1600° C. Suction 100° C.	E_3 Max. 1000° C. Suction 0° C.	E_4 Max. 1000° C. Suction 100° C.
$\frac{1}{4}$	0·43	0·385	0·380	0·378	0·367
$\frac{1}{5}$	0·47	0·424	0·417	0·415	0·401
$\frac{1}{7}$	0·55	0·476	0·468	0·462	0·440
$\frac{1}{10}$	0·61	0·521	0·507	0·591	0·467

Table IV. shows the proportion of heat added during expansion to total heat added at constant volume, heat added at constant volume being taken as unity.

Table IV.—Heat added during Expansion. Heat added Constant Volume I.

$\frac{1}{r}$	Compression $PV^{1\cdot408}$, Expansion $PV^{1\cdot2}$. Max. 1600° C. Suction 0° C.	Max. 1600° C. Suction 100° C	Max. 1000° C. Suction 0° C.	Max. 1000° C. Suction 100° C.
$\frac{1}{4}$	0·34	0·398	0·403	0·522
$\frac{1}{5}$	0·40	0·466	0·486	0·663
$\frac{1}{7}$	0·496	0·600	0·640	0·962
$\frac{1}{10}$	0·616	0·788	0·852	1·55

Taking $\frac{1}{r}$ as one-tenth, the heat added in the 1,600 degs. to 0 deg. Cent. case is 0·616 of the heat added at constant volume, while in the 1,000 degs. to 100 degs. Cent. case it is 1·55 times that quantity. As these heat additions are made at lower and lower compressions, it is easy to see that, under these circumstances, lower efficiencies are obtainable. These figures clearly show the desirability of adding all the heat if possible at constant volume ; that is, of avoiding all heat additions during expansion. If this cannot be done, then as little heat as possible should be added during expansion, and the maximum temperature should be kept up while the suction temperature should be kept down.

(To be concluded.)

NEW MACHINERY & APPLIANCES

Superheating and Coal Consumption.

THE utilisation of the waste heat of boilers is a problem which has engaged the attention of engineers almost ever since the introduction of steam as a motive power. It is well known that, of the total amount of heat generated in a boiler, about 90 per cent. is entirely wasted, and only 10 per cent. usefully employed. To make some use of this waste the Central Marine Engine Company, of West Hartlepool, have devised an installation in which the steam, after leaving the boiler, is superheated before admission to the engine by being passed through a number of tubes, which are heated by the waste gases prior to their exit through the funnel.

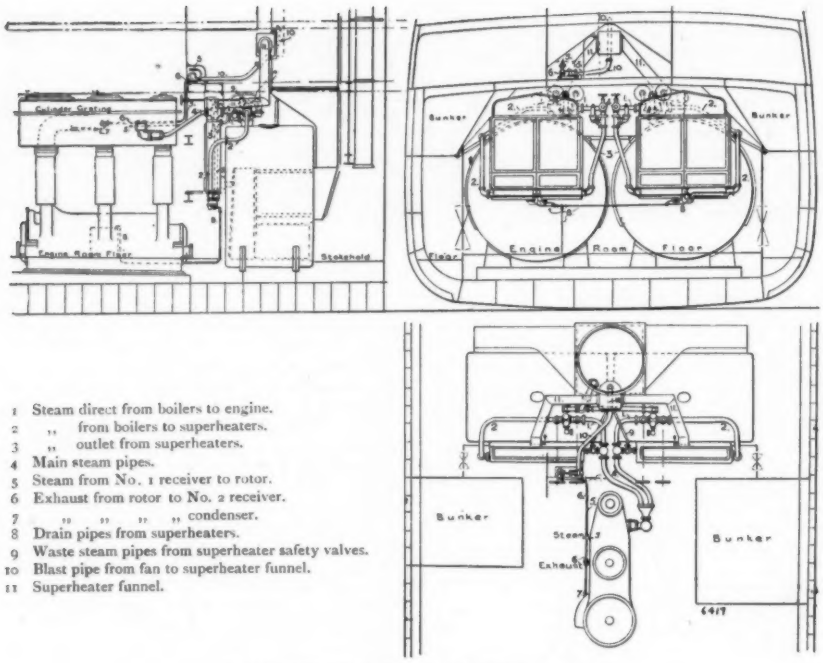
The first installations of this kind were fitted to some of the Inch Line boats owned by Messrs. Hamilton Frazer, of Liverpool, in 1900, which, in place of the usual triple-expansion engines, were supplied with the five-cylinder quadruple-expansion type so closely associated with the name of the late Mr. Mudd.

The *Inchmarlo*, one of the boats with this installation on board, recently completed a 380 days' voyage nearly all round the world, with an average coal consumption of 15¼ tons per day at a speed of 9 knots, on a carrying capacity of 5,700 tons. This works out at practically 1 lb. of coal consumed per i.h.p. per hour, a feat in coal consumption which has hitherto never even been approached. The amount of coal on which this result is based is the actual quantity paid for by the owners.

We are enabled, by the courtesy of the Central Marine Co., to illustrate the latest development of this unique apparatus, as fitted to some vessels at present being completed by them. The general arrangement can be clearly seen from the accompanying diagrams. The superheater is placed at the back of the boilers, and consists of a number of wavy tubes, so arranged as to maintain the steam in passage in a continual state of agitation, in order that it may come continuously into contact with the hot metal. The waste gases are admitted to the superheater through an opening in the back of the boiler. From the diagrams it can readily be seen that the heat will be greatest at the base, and gradually diminish as it approaches the funnel. On this account the steam is led direct from the main stop-valve to the top of the superheater, thence it works its way down, the temperature being gradually raised in passage, and finally is conducted to the engine after having attained a temperature of about 500 degs. Fahr.

The figures received from one of the latest vessels show that a saving of 10 per cent. in fuel is being effected. The boiler is of the ordinary cylindrical type, with a pressure of 160 lbs. per square inch, corresponding to a temperature of 370 degs. Fahr. With this apparatus it is raised to 500 degs. Fahr. before admission to the engines. It can be generally stated that for every 10 per cent. increase in temperature a saving of 1 per cent. in fuel is effected. As can be seen from the drawings, separate valves are so arranged that steam may be led direct from the boilers to the engines without being passed through the superheater, if this is desired.

Hitherto, reliance has been placed on the natural draught, due to the superheater funnel being situated inside the main one, to draw the waste gases through the apparatus; but experience has shown that with certain degrees of wind there is a tendency to blow down the smaller funnel, and thus impair the efficiency. To obviate this in future installations, there has been introduced into the system a small rotor and fan, which in effect is a triple-expansion turbine. This is termed the "Central" rotor, and by means of it a constant updraught is ensured, thereby drawing the hot gases right up through the superheater. This can be located in any convenient position, and the blast-pipe led into the superheater funnel. It is confidently hoped that a steam temperature of 520 degs. Fahr. and a saving of 15 per cent. in fuel may be maintained in the cases of two vessels at present having the installation supplied.



1 Steam direct from boilers to engine.
2 ,, from boilers to superheaters.
3 ,, outlet from superheaters.
4 Main steam pipes.
5 Steam from No. 1 receiver to rotor.
6 Exhaust from rotor to No. 2 receiver.
7 ,, ,, ,, ,, condenser.
8 Drain pipes from superheaters.
9 Waste steam pipes from superheater safety valves.
10 Blast pipe from fan to superheater funnel.
11 Superheater funnel.

ARRANGEMENT OF "CENTRAL" SUPERHEATER.

Electric Rail Autocar, North-Eastern Railway.

REFERENCE has already been made in THE ENGINEERING REVIEW* to the interesting development in railway automobilism marked by the introduction of electric autocars on the North-Eastern Railway. On that occasion, however, we were chiefly concerned with the details of the petrol-engine used for driving the electric generator; but we are now able to present a more detailed description of the car itself, the trials of which have given every satisfaction.

The car, as will be seen from the accompanying illustrations, is of the ordinary bogie saloon type with clerestory roof, and is 52 ft. over headstocks, with an inside width of 7 ft. 11 ins. It is divided into three compartments: that at the forward end containing the petrol-engine and generator, the central portion accommodating the passengers, whilst the rear compartment contains the machinery for operating the car when running that end foremost. A gangway divides the first and central portions, permitting of entrance to either the engine or passenger compartment.

Seating accommodation, to the extent of 52 passengers, is provided by two rows of reversible seats, which are upholstered in the North-Eastern Company's usual style; a gangway separates the rows of seats, and the floor is covered with linoleum.

The windows are fitted with curtains, and the lighting is by means of 24 16-c.p. incandescent lamps, current for which is supplied from accumulators carried under the centre of the car. A series of radiators provides an efficient source of heat for winter service, and altogether the car is very cosily arranged for the comfort of the passengers.

Buffers, coupling-hooks, and chains have been fitted, so that the car can be run with ordinary rolling-stock. The head and rear lights are electrically fitted.

The engine compartment is 13 ft. 3 ins. long, and contains the 80-b.h.p. 4-cylinder horizontal petrol-engine built by Messrs. The Wolseley Tool & Motor Car Co., Adderley Park, Birmingham, and is fully illustrated in

* Cf. pp. 248-50.

the article previously mentioned. The cylinders are 8½ ins. diameter by 10 ins. stroke, and the normal speed of running is 420 revolutions per minute, which can be accelerated to 480 revolutions per minute for starting the car quickly.

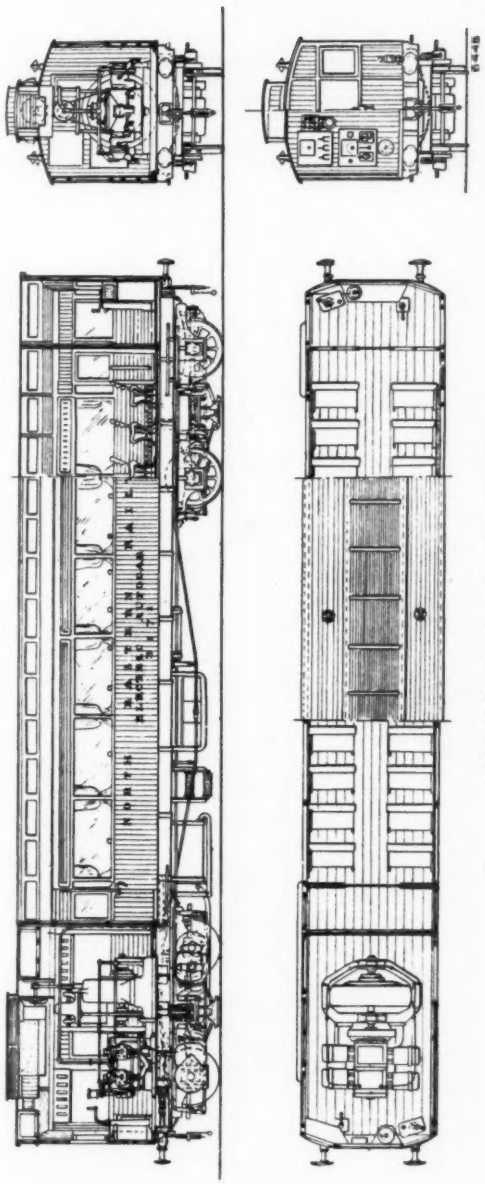
The cylinders are overhung on a stiffly constructed cast-iron crank-chamber, the inspection covers being on the top and the oil trough beneath. Forced lubrication is used for all the main bearings. The flywheel, which is truly balanced, is 3 ft. in diameter; all the valves are mechanically operated by cams on the two cam-shafts, and these shafts are driven by means of spiral gearing and lay-shafts from the crank-shaft. The latter is of the "two-throw" type, and of Vickers-Maxim cast-steel.

The engine cylinders and valve-boxes are water-cooled, a Clarkson radiator and Blackman fan being employed for the cooling of the water.

The engine is governed on the throttle, and in addition auxiliary hand-throttling is fitted, so that the driver can accelerate the engine speed from either end of the car. The ignition is by means of the usual high-tension system.

The motor is direct-coupled to the generator, which is a separately excited and compound-wound, direct-current engine-type machine of 55-kw. capacity, specially designed for operating over a range of voltage from 300 to 550. This machine operates at a normal speed of 420 revolutions per minute, and is supported on an extended bed-plate, the armature being pressed on to the extended engine-shaft, provided with a flanged coupling between the generator and motor. The field of the generator is split horizontally, so that the upper half may be removed for access to the armature or field coils through an opening in the roof of the car, fitted with a removable cover.

The exciter is a 3·75-kw. standard 72-volt shunt-wound belt-driven multipolar generator,



ELECTRIC RAIL AUTOCAR, NORTH EASTERN RAILWAY.

mounted above the main generator and belted to a pulley on the extended shaft. This machine is capable of exciting the main generator and of supplying current for lighting 30- to 72-volt 16-c.p. incandescent lamps. The voltage of this machine may be increased to 95 volts for charging the battery when not required for lighting.

Two Westinghouse No. 56-55-h.p. standard railway motors, with single reduction gears, ratio 18 to 64, are mounted on the front bogie by means of a nose suspension bar, with spring attached to the bogie frame. These motors are series-wound, and are of the standard type usually employed for operating heavy high-speed tram cars.

The controllers are the standard series-parallel tramway type arranged for electric braking. Resistances are provided in connection with the controllers for gradually increasing the voltage of motors in starting the trains, and for graduating the electric brake in stopping. These resistances are mounted beneath the car.

The storage battery consists of 38 cells in ebonite jars, assembled in a wooden box suspended beneath the car. Each battery has a capacity of 120 amp. hrs.

The electric brake equipment consists of two electro-magnets suspended between the wheels of each truck and immediately above the track-rail. It is so constructed that the magnetic circuit is completed through the track-rail, so that when the coils are energised the magnet is attracted to the rail, thus causing friction between the magnet and the rail and retarding the motion of the car. This retarding action brings pressure to bear upon the brake-shoe applied to the wheel, which further retards the motion of the car; and this friction of the magnet on the track and the brake-shoes on the wheels is sufficient to bring the car to a stop in an extremely short distance. The brake-coils are energised by the current from the motors operating as generators, and this action further absorbs energy in starting the car and adds to the braking power. This feature also renders the brake perfectly reliable, as it does not depend upon the generator plant for the supply of power.

An air compressor is located on the rear bogie and supplies air for blowing an alarm whistle. The compressor is driven by a 1-h.p. electric motor, and is started and stopped by means of pressure controlling switches and cut-outs, thus automatically maintaining a constant pressure in the air reservoir which supplies the whistle.

The whole of the electric equipment has been supplied by Messrs. The British Westinghouse Electric & Manufacturing Co., Ltd., Manchester.

The system of working is as follows: The current passes from the generator through an automatic circuit-breaker to the two controllers, and the voltage of the generator is adjusted by means of a rheostat in the field circuit, placed near the controller at each end of the car. The generator is used as a motor, supplied with current from the storage battery, for starting up the petrol motor. After having brought the engine and generator up to speed and the pressure has been adjusted to 400 volts, the car is started in the usual way by manipulating the handle of the series-parallel controller to series-point for slow speed and to the multiple-point for high speed. Afterwards the voltage of the generator is gradually increased to 550 by manipulating the field rheostat near the controller.

At this pressure the car will accelerate until a constant speed of 36 mls. per hour is attained. In stopping the car the controller handle is moved back to the off position, and then in a reverse direction over the breaking points, thus applying the magnetic track brake. As soon as the car is brought to a standstill, the generator field rheostat is readjusted to give 400 volts, and it is then in a position for restarting. If it is desired to operate the car at half-speed, the voltage may be raised to 550 volts by adjustment of the rheostat with the controller handle at the full-series point.

From this it will be seen that a range of speed is obtainable by variation in the voltage of the generator at two points—viz., approximately half-speed and at full speed.

These cars can be put into service at ten minutes' notice, and they carry a supply of both fuel and water for a full day's work, and they can be driven from either end with equal facility.

The weight of the car in full working order is 35 tons.

The Iron and Steel Institute.

Abstracts of Papers read at the May Meeting.

Notes on the Production and Thermal Treatment of Steel in Large Masses. **Cosmo Johns.**

In works practice the influence of mass plays a not unimportant part, an influence which in laboratory experiments is insignificant; hence the author desires to differentiate between the two. For instance, a railway axle weighing 500 lbs. offers a mass out of all proportion to the small specimens experimented upon under laboratory conditions; and yet axles are about the smallest of the steel products of the River Don Works, Sheffield, with which the author is connected. From an axle weighing 500 lbs. to a marine shaft 26¼ ins. external diameter and 86 ft. in length is a stride that at once emphasises these conditions. To ensure the homogeneity of such a mass is alone a problem; whilst to heat it equally to a predetermined temperature and then to cool it at a certain rate are operations that tax the resources of the metallurgical engineer. Further, time is an important factor in thermal treatment, for if a small specimen and a large forging, both of the same composition, be subjected to the same heat treatment, the resulting structures will be very different. One of the first lessons learnt in works practice is that heat treatment eminently suitable for a small specimen as determined by the laboratory requires careful revision and a consideration of the new factors of "time" and "mass" before satisfactory results are obtained in the works. From a manufacturing point of view the specification must be added to time and mass, and these three factors present the chief differences between works and laboratory practice. The methods of manufacture and special products of the River Don Works are described. For these products chemical purity is essential, and no difficulty is found in regularly obtaining contents of sulphur and phosphorus under 0·035 per cent. The danger of segregation, whilst always present, may be largely minimised by correct design and starting with initially pure materials. Before casting, the steel should be "well killed"; it should teem quietly and remain still and limpid in the moulds. Any attempt to secure this by large additions of deoxidisers to the ladle will result in variation in the composition of the steel; whilst there will be the further difficulty that the oxides ormed have not time to rise to the surface of ingot or mould. The importance of casting in open moulds with suitably designed feeding-heads is also emphasised, and the author advises no attempt by extraneous pressure to compress the fluid steel, for such compression serves only to mask the defects of bad melting by diminishing the volume of blowholes which, with good melting, should not have existed.—P. L.

The Plastic Yielding of Iron and Steel. **Walter Rosenhain, B.Sc.**

In the first portion of this paper the author examines the recently published views of Osmond, Frémont, and Cartaud on the "Modes of Deformation of Iron and Soft Steel."* The deductions of these observers are not in accordance with the previously published ones of Ewing and Rosenhain, and the author has therefore re-examined the evidence on which those views were formed. To some extent this involves a repetition of previously published matter. It will, however, be remembered that the fundamental phenomenon on which the views enunciated by Ewing and Rosenhain are based is the change in appearance when a previously polished and etched specimen of iron or other metal is plastically deformed and then again examined under the microscope. Previous to straining the section is divided into the well-known polygonal areas which mark the crystalline grains of the metal, whilst after deformation the areas of the crystalline grains are seen to be cross-hatched with a number of fine black lines. These lines are seen to be in a general way parallel to one another within the area of each crystalline grain, but to have different directions in different grains. These black lines denote the "slip bands" of Ewing and Rosenhain, the crystalline character of which Osmond, Frémont, and Cartaud do not accept. The author, by further examination, concludes that these deformations are of a crystalline nature, and attaches importance to their examination by oblique light, a source of illumination not adopted by Osmond, Frémont, and Cartaud. Finally, slip bands

* Abstracted on p. 187, Feb. issue of THE ENGINEERING REVIEW.

which appear as continuous but curved lines under vertical light are, when examined with the highest power available with oblique illumination, resolved into discontinuous lines, whose curvature is much less apparent. The dark gaps in the slip bands as seen under oblique illumination are ascribed to minute steps along gliding surfaces having a different orientation. The curvature of slip bands in iron being probably due to a multitude of minute steps, a reason is suggested why this stepping should be so marked a feature in iron while it is so comparatively rare in certain other metals. This reason is, that the ferrite crystals are formed by crystallisation from a solid solution, while the ordinary crystals of lead, for instance, are formed by crystallisation from a true liquid. The crystalline character of slip bands is also further shown by the observation of slip bands in iron following and revealing the gliding planes of twin crystals.—P. L.

The Influence of Casting Temperature on the Properties of Iron and Steel Castings. **Percy Longmuir** (Carnegie Research Scholar).

Table I. shows the influence of casting temperature on the properties of a typical white and grey iron and of an unsound type of white iron. Nos. 34, 35, and 36, poured at selected temperatures from one crucible, yield tenacities of 10·7, 15·9, and 12·1 tons per sq. in. respectively. On annealing companion bars the distance apart is still maintained, as the tenacities of 20·6, 29·2, and 26·5 tons per sq. in. show. Similarly the grey iron shows the influence of varying casting temperature, the "high," "fair," and "low" casting heats yielding tenacities of 9·7, 14·1, and 10·6 respectively. In many experiments with mild crucible steels it was found almost impossible to attain typical high-casting temperatures. A series of side-blown Bessemer castings were therefore obtained; and, as from this method exceptionally high temperatures in the case of even mild steels may be obtained, some important results have been obtained. These are included in Table III. Particular attention is drawn to the influence of casting-temperature on the extensibility. The results also show that the crystalline habit induced by high or low casting-temperature is not eliminated on annealing. From the experiments on crucible steels, in which the metal was not overheated but cast at typical "fair" or "low" casting heats, the variations in properties as shown by the tensile test are not noteworthy. Low casting temperatures, however, appear to induce a type of brittleness which, whilst not shown in the tensile test, is evidenced in the working life of the steel. From results already obtained (further ones being in progress) the author concludes that one source of mysterious fracture may be traced to the original ingot having been cast at either too high or too low a casting temperature. In this respect the results embodied in Table V. are worthy of examination. It will be noted that the tensile properties of Nos. 99 and 100, representing fair and low casting heats from one

TABLE I.

No.	Analysis.						Casting Temperature.	Condition.	Mechanical Properties.		
	CC.	Gr.	Si.	Mn.	S.	P.			Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Prolongation % on 2 ins.
34 ...	3·4	.....	0·39	0·05	0·02	0·02	1320° C.	As cast	.. ...	10·7	... ..
35 ...	,,	.....	,,	,,	,,	,,	1230° C.	,, ,,	.....	15·9	.....
36 ...	,,	.....	,,	,,	,,	,,	1120° C.	,, ,,	.....	12·1	.....
34 A.	0·2 to 0·5[1]	3·2	,,	,,	,,	,,	1320° C.	Annealed 100 hrs. in ore	20·0	20·6	1·0
35 A.	,,	,,	,,	,,	,,	,,	1230° C.		24·3	29·2	3·5
36 A	,,	,,	,,	,,	,,	,,	1120° C.		22·5	26·5	2·0
37 ...	0·52	3·4	1·78	0·28	0·04	0·27	1400° C.	As cast	.....	9·7	.....
38 ...	,,	,,	,,	,,	,,	,,	1350° C.	,, ,,	.....	14·1	.....
39 ...	,,	,,	,,	,,	,,	,,	1245° C.	,, ,,	... ...	10·6	... ...
43 ...	3·35	.....	0·03	0·03	0·02	0·02	1440° C.	As cast	.....	9·4	.....
44 ...	,,	.....	.....	... ...	.....	.....	1209° C.	,, ,,	.....	12·1	.....

[1] Varies according to proximity of drillings to outside or centre of bars from 0 to 0·2 and 0·5.

TABLE III.—THE INFLUENCE OF VARYING CASTING TEMPERATURE ON THE PROPERTIES OF STEEL CASTINGS OF IDENTICAL COMPOSITION POURED FROM ONE HEAT.

No.	Analysis. C.C.	Si.	Mn.	S.	P.	Condition.	Mechanical Properties. Elastic Limit. Tons Sq. In.	Max. Stress. Tons Sq. In.	Elongation % on 2".	Reduction of Area %.	Remarks.
80 ...	0·29	0·07	0·16	0·07	0·06	As cast	13·5	20·3	5·0	7·7	Poured in rotation at intervals from "high" to "low" during one cast
81 ...	,,	,,	,,	,,	,,	,,	14·3	24·2	9·0	12·9	
82 ...	,,	,,	,,	,,	,,	,,	13·6	26·0	10·0	10·0	
83 ...	,,	,,	,,	,,	,,	,,	12·8	25·0	8·5	10·8	
80A ...	,,	,,	,,	,,	,,	Annealed	12·5	24·2	9·5	18·0	80 to 83 Annealed
81A ...	,,	,,	,,	,,	,,	,,	13·5	27·2	24·0	32·3	
82A ...	,,	,,	,,	,,	,,	,,	13·3	27·0	12·5	17·5	.....
83A ...	,,	,,	,,	,,	,,	,,	13·2	25·5	8·0	12·0	.....
90 ...	0·20	0·04	0·38	0·15	0·06	As cast	11·7	14·2	3·5	7·0	Ex. of the influence of varying casting temp. on a mild steel fairly high in sulphur
91 ...	,,	,,	,,	,,	,,	,,	14·8	21·5	5·0	8·6	
92 ...	,,	,,	,,	,,	,,	,,	13·8	21·4	6·0	9·1	
93 ...	,,	,,	,,	,,	,,	,,	12·6	17·5	3·5	8·0	
90A ...	,,	,,	,,	,,	,,	Annealed	11·4	15·8	6·5	11·2	90 to 93 Annealed.
91A ...	,,	,,	,,	,,	,,	,,	13·0	22·1	7·5	13·4	
92A ...	,,	,,	,,	,,	,,	,,	12·5	21·8	10·0	9·2	.....
93A ..	,,	,,	,,	,,	,,	,,	12·2	20·8	10·0	9·0	.. ...
90HT	,,	,,	,,	,,	,,	Heated to 1000° C. & slowly cooled	13·5	15·5	5·0	8·0	90A, 91A, 92A, & 93A heated to 1000° C. and slowly cooled
91HT	,,	,,	,,	,,	,,		14·2	15·7	8·0	9·0	
92HT	,,	,,	,,	,,	,,		14·9	22·9	11·0	12·0	
93HT	,,	,,	,,	,,	,,		14·1	20·7	10·0	11·0	

crucible, are practically identical. Yet these two steels show a marked dissimilarity when tested by alternation of stress. The microscopical results indicate that casting temperature has a distinct influence on the intercrystalline cohesion, and also that this influence survives the annealing process.—P. L.

The Range of Solidification and the Critical Ranges of Iron Carbon Alloys. **H. C. H. Carpenter, M.A., Ph.D.; B. F. E. Keeling, B.A.** (both of the National Physical Laboratory).

This research represents a determination of the melting points of a series of iron carbon alloys, and an investigation of all the evolutions of heat in the alloys from the beginning of solidification down to 500 degs. Cent. The results obtained are embodied in the accompanying table. It will be noted that the authors have confirmed the existence of the change Ar.O previously detected by Roberts, Austen and Stansfield.—P. L.

TABLE V.—THE INFLUENCE OF VARYING CASTING TEMPERATURE ON THE PROPERTIES OF STEEL AS EVIDENCED BY ALTERNATION OF STRESS.

(Data: 270 reversals per minute; $\frac{5}{16}$ in. stroke; test piece, $\frac{3}{4}$ in. by $\frac{3}{8}$ in.)

No.	Casting Temperature.	Condition.	Reversals to Complete Fracture.	Maximum Stress. Tons per sq. in.	Elongation % on 2 ins.
97 ...	1550° to 1600°	As Cast.	68	35·8	12·5
98 ...	1470° to 1500°	,, ,,	48	34·2	11·5
97 A.	1550° to 1600°	Annealed.	122	27·0	17·5
98 A.	1470° to 1500°	,,	62	28·2	18·5
99 ...	1550° to 1600°	Forged	546	40·9	27·5
100...	1470° to 1500°	,,	172	40·1	28·0

The Manufacture of Pig Iron from Briquettes at Herräng. **Prof. Henry Louis, M.A., A.R.S.M.**

The mines are at present worked open cast and the ore conveyed by aërial wire rope-ways to the crushing works. The ore passes first to a large crusher of the Gates pattern, which reduces it to about 2 ins. cube. This product is divided by means of shoots between two smaller breakers, which effect a further reduction to about ½-in cube. This broken ore is distributed to the feed hoppers of four wet-crushing Gröndal ball mills. The mills consist of horizontal cylinders 40 ins. in length and 80 ins. in diameter, built up of longitudinal steel-ribs 0·33 in. deep with cast-iron end-plates, through one of which the ore is introduced together with water, escaping as pulp in a finely-ground condition through the other end-plate. Each mill is charged with about 2 tons of chilled cast-iron balls ranging in size from 6 ins. diameter downwards. These mills make 28 revolutions per minute, require 20 to 25 h.p. each to drive them, and will grind from 50 to 100 tons of ore each per

THE RANGE OF SOLIDIFICATION AND THE CRITICAL RANGES OF IRON CARBON ALLOYS.

1	2	3	4	5	6	7	8	9	10	11	12
Alloy No.	Carbon %	Range of Solidification.		Ar. m.c.	Ar. 3.		Ar. 2.		Ar. 1.		Ar. 0.
		Beginning	End	Beginning	Beginning	Maximum	Beginning	Maximum	Beginning	Maximum	Beginning
1	0·01	...	...	...	901	900	784	762	...	...	616
2	0·02	1504°	1470°	...	900	890	795	762	...	...	600
3	0·05	...	...	...	905	884	780	762	...	...	...
4	0·12	1504†	1470†	...	894	838	774	762	693	688	600
5	0·16	1498†	1465†	...	872	837	771	762	697	693	576
6	0·17	1497†	1450†	...	...	...	...	...	...	...	...
7	0·24	1492†	1448†	...	890	Merged	...	762	696	693	611
8	0·38	1479†	1416†	...	...	...	778	762	700	699	...
9	0·47	1482†	...	...	...	...	777	762	...	703	587
10	0·53	1473†	1404†	...	...	...	762	730	...	700	617
11	0·61	1469†	1394†	...	...	...	780	Merged	Merged	699	593
12	0·80	1457‡	1351‡	...	...	...	...	...	...	(704)	...
13	0·80	1454†	...	...	...	...	...	...	...	(695)	...
14	0·81	1460†	1351†	...	774	Merged	...	Merged	Merged	706 (705)	...
15	0·93	1443†	...	...	774	,,	...	,,	,,	699	587
16	1·31	1426†	1286†	883	774	,,	...	,,	,,	(711) 695	600
17	1·51	1406†	1244†	911	768	,,	...	,,	,,	(713) 684	587
18	1·69	1388†	...	985	774	...	...	...	...	(708) 710	...
19	1·81	1383†	...	...	...	...	...	...	...	...	...
20	1·85	1383†	1179†	(1015) 1030	783	Merged	...	Merged	Merged	(711) 711	...
21	1·97	1367†	...	(1042)	...	...	...	...	...	(710)	..
22	2·12	1350†	1110†	...	...	...	...	...	...	(714)	...
23	2·21	1354†	1107†	...	801	Merged	...	Merged	Merged	714	610
24	2·25	1352†	1122†	...	...	...	..	...	...	...	...
25	2·25	1348†	1122†	...	...	...	...	...	...	(714)	...
26	2·47	1330†	1134†	1035	801	Merged	..	Merged	Merged	708	622
27	2·62	1305†	...	1040	801	...	...	...	..	716	610
28	2·67	1306†	...	...	...	...	...	...	...	...	...
29	2·74	1300†	1139†	...	...	...	...	...	...	...	...
30	2·85	1292†	1139†	1058	...	Merged	...	Merged	Merged	716 (715)	613
31	3·03	1277†	1139†	...	777	,,	...	,,	,,	702 (717)	610
32	3·29	...	1141†	...	...	...	...	...	...	...	...
33	3·42	1238†	1114†	1058	790	Merged	...	Merged	Merged	703 (714)	610
34	3·51	1230†	1136†	...	...	...	..	...	..	...	...
35	3·87	1190†	1144†	1090	770	Merged	...	Merged	Merged	(716) 716	600
36	3·98	1171°	1138°	1087	...	...	...	...	...	713	604
37	4·37	1136°	1136°	...	...	...	...	...	...	(714)	...
38	4·5	1146°	1146°	1087	777	Merged	...	Merged	Merged	715	616

° Thermo-junction M_1 platinum platinum 10 per cent. iridium.
† ,, M_2 ,, ,, ,, ,, rhodium.
‡ ,, M_3 ,, ,, ,, ,, rhodium.
The temperatures in brackets in columns 5 and 11 were obtained by direct cooling.
All other temperatures in columns 5 to 12 were obtained by differential cooling.
Ar. m.c. represents separation of massive cementite.
Ar. 3 ,, change from γ to β iron.
Ar. 2 ,, ,, ,, β to α iron.
Ar. 1 ,, ,, ,, hardening carbon to pearlite carbon.
Ar. 0 ?

24 hours. The pulp passes to the magnetic separators, each consisting first of the magnetic-slime box and secondly of the separator proper. It consists of a V-box receiving a stream of clear water. Between each pair of these V-boxes is a powerful horizontal electro-magnet, either pole of which terminates in a hatchet-shaped pole-piece, the edge of which nearly touches the level of the pulp in the box. The dimensions of the box and the velocities of the pulp and clear-water currents are so arranged that everything except the finest slimes settles in the box and passes through a pipe to the magnetic separator, the fine slimes overflowing. Any magnetic slime is arrested when it comes within the powerful magnetic-field produced by the pole piece, and accumulates at the surface of the water until it forms masses of such size as to drop down and be carried away by the issuing stream of water; the object being to eliminate the bulk of the non-magnetic slimes whilst ensuring that none of the magnetic material shall be lost. The pulp, freed from slime, now passes to the separators proper. A magnet with pole pieces of the same shape as those used for the slime boxes is surrounded by a drum composed of alternate bars of soft iron and brass. This drum rotates at 100 revolutions per minute, about 1 in. above the surface of the pulp, which traverses a pyramidal box, this being divided into two compartments by a partition reaching nearly up to the top of the box. A stream of clear water entering and rising up on one side of the partition carries the pulp well over the edge of the latter and thus into close contact with the drum. The bars of iron composing the latter become powerful magnets so long as they are within the strong magnetic-field of the pole piece, and they pick up all magnetic particles from the stream of pulp. The remainder of the pulp drops down on the other side of the partition, and is carried off by the stream of water. The pure magnetite is lifted by the drum to the very edge of the magnetic field, where it is thrown off by the speed at which the drum revolves. The middlings, consisting of particles that are in part magnetite and in part barren rock, are flung off before they reach so weak a part of the field; these are returned to the ball-mills. The concentrates pass on to a large store, where the material remains about a week to drain. It is then lifted by a bucket elevator to the hoppers feeding a couple of briquetting presses. These are drop presses, the plunger being lifted by a three-throw cam so that each briquette receives three blows, the height of the drop ranging from 6½ ins. to 7½ ins., and the falling weight being 16 cwts. Each press makes 8 to 12 briquettes per minute, about 6 × 6 × 3 ins., and weighing about 10 lbs. each. From the press they are placed in cars, each car holding about 15 cwts. of briquettes. The cars are transferred to a long tunnel-shaped gas-fired furnace. Three of these furnaces yield an output of 100 tons per 24 hours. The temperature in the combustion chamber reaches 1300 degs. Cent., and at this heat the magnetite agglutinates sufficiently to form a firm, hard briquette. The briquetting furnace also acts as an efficient calciner for removing practically the whole of the sulphur contained in the ore. The briquettes are broken in a small Blake stone-breaker into pieces of convenient size for charging into the blast furnace, an inclined hoist conveying the broken material to the charging platform of the blast furnaces. The charcoal consumption in the blast furnaces is under 14 cwts. per ton of pig, an exceptionally low figure, whilst the output of the furnaces is exceptionally large, these advantages being attained by the smelting of briquettes instead of ore.—P. L.

The Manufacture of Coke in the Hüssener Oven at the Clarence Iron Works, and its Value in the Blast Furnace. **C. Lowthian Bell.**

The Hüssener oven is described and illustrated in detail. During 1903 some 105,000 tons of coal as received from the collieries have been treated, yielding 65·5 per cent. of good blast-furnace coke and 2·19 per cent. of breeze. On washed coal the yield has been: good blast-furnace coke, 72·04 per cent.; and breeze, 2·41 per cent. The hardness of the coke is shown by the small proportion of breeze—viz., coke, 96·77, and breeze, 3·23 per cent. The average analysis of the coke has been: moisture, 3·97 per cent.; ash, 8·18 per cent.; sulphur, 1·03 per cent.; volatile matter, 0·82 per cent.; fixed carbon, 86·00 per cent. At present the bye-products obtained are tar and sulphate of ammonia, the benzol works having only just been completed. The yield of tar has been 1·06 cwts. and 0·33 cwts. of sulphate per ton of coke. The cost for repairs over the last twelve months has been—wages, 0·98, and stores, 0·62 pence per ton of coke. —P. L.

Explosions produced by Ferro-Silicon.—**A. Dupré, Ph.D., F.R.S.,** and **Captain M. B. Lloyd, R.A.**

The authors have investigated several

explosions which occurred in connection with a consignment of ferro-silicon from the s.s. *Veria* at the Alexandra Dock, Liverpool. These studies lead to the opinion that the explosions were probably caused by water entering the interior of the drums containing the ferro-silicon. The gas evolved formed with the air in the drums an easily ignited explosive mixture, which was fired by the heat produced by the friction of the hard lumps against each other; or possibly by the spontaneous ignition of some phosphoretted hydrogen contained in a pocket of the material, and liberated suddenly by the breaking of a lump on the drum being moved.—P. L.

CATALOGUES RECEIVED.

Wolstenholme, John & Son, Albert Iron & Brass Works, Radcliffe, near Manchester. A comprehensive and fully illustrated catalogue of sewerage ironwork, including various new types and articles recently introduced.

John I. Thornycroft & Co., Ltd., Chiswick, London, W. This is without doubt one of the finest examples of catalogue work that it has been our pleasure to receive. In it are described and illustrated marine motors and launches of various types suited to such widely different purposes as racing boats, cruising boats, ferry boats, etc. The Thornycroft motors with which they are fitted are claimed to be of British workmanship and material throughout, which enable this firm to compete very successfully with foreign manufacturers.

Bath Electric Manufacturing Co., Ltd., Locksbrook Engineering Works, Bath. Pamphlet No. 15, dealing with the "Kramos" resistance-piece, an electroceramic product, quite original in its composition, and which appears to be possessed of some extremely valuable qualities.

W. N. Brunton & Son, Musselburgh, N.B. New edition of "Resistance Material Catalogue," dealing with the specialities which this firm is now manufacturing for the electrical trades, as well as resistance material, such as cable clips, arc lamp rope, etc., etc. The tables giving resistance, carrying capacity, etc., of the "Beacon" high resistance wire have also all been revised.

T. W. Broadbent, A.M.I.E.E., Victoria Electrical Works, Huddersfield. Illustrated booklet giving probable buyers of electrical goods an approximate estimate of cost.

Jessop & Appleby Bros. (Leicester & London), Ltd., 22, Walbrook, Cannon Street, E.C. A handsome and well-illustrated catalogue of electric cranes of standard, and a few special types, also electrically-driven winches, lifts, concrete mixers, and pile drivers, with notes and general information.

Consolidated Pneumatic Tool Co., Ltd., Palace Chambers, 9, Bridge Street, Westminster. A supplement to the 1904 catalogue, dealing with the "Boyer" hammer fitted with rotating device for driving plugholes in stonework and for riveting copper stays.

New Brotherton Tube Co., Ltd., Commercial Road, Wolverhampton. New list of "Excelsior" enamelled steel conduit tubes and fittings for electric wiring, together with a description of their well-known "Excelsior" system of electrical conduit.

Campbell Gas Engine Co., Ltd., Halifax. Illustrated list of the latest types of "Campbell" oil engines. The makers state that with these engines the oil consumption has been reduced 25 per cent., the cheapest brands of petroleum only being used.

Croft & Perkins, Leeds Road, Bradford. Two very fine examples of what a catalogue should be, entitled "Power Transmitting Machinery" and "Friction Clutches." They are amongst the most comprehensive, best illustrated, and complete editions of this class of product that have been published.

The Nicholson Tool Co., City Road Tool Works, Newcastle-on-Tyne. New abridged pocket catalogue of standard machine and hand tools.

Gibbons Bros. Ltd., Dibdale Works, Dudley. Price lists of gear wheels, driving belts, conveyor bands, and spiral conveyors.

Fleming, Birkby & Goodall, Ltd., West Grove Mill, Halifax. Well illustrated sectionised catalogue of belting and card manufactures, with useful hints, mechanical data, and other information at the end.

W. H. Bailey & Co., Ltd., Albion Works, Salford, Manchester. Pamphlets 213 and 254, describing respectively Bailey's "Patent Steam Stop Valves" and "Improved Air Lift System" for raising water from deep wells.

ENGINEERING ABSTRACTS

For List of Publications regularly reviewed see previous issue, pp. 351—352.

On Cylinder Condensation and Valve Leakage in Steam Engines. IV.

THE object of the McGill experiments referred to was to find, by actual measurement, the quantity of heat which entered and left the cylinder walls per cycle, by reason of condensation and re-evaporation of steam thereon. The cylinder used was 10·5 ins. diam., and 12 ins. stroke, and was single acting. Holes were bored to different depths in the cylinder end, and a thermo-couple pressed against the bottom of each hole was found to give the temperature at that point to about $\frac{1}{16}$° Fahr. A circular contact maker was used, which, rotating with the engine-shaft, could be arranged to close the thermo-junction-galvanometer circuit at any assigned point of the revolution, so that by successive contacts at each particular crank-angle the temperature at the given depths could be accurately noted. Indicator cards were taken from the cylinder at the same time, and in addition a delicate platinum thermometer was inserted among the cylinder steam, through a hole in the piston-rod. The pressures given on the indicator cards being converted into temperatures by Regnault's steam-tables, the author thus had three methods of measuring the temperature for any crank position. These three methods were all in very close agreement. The following table gives the figures for one of the trials :—

TABLE OF STEAM AND WALL TEMPERATURES IN FAHR. DEGREES.

Revolutions, 73·4 per minute ; initial pressure, 98 lbs. abs. ; non-condensing ; cut off, ·2 stroke.

	°	°	°	°	°	°	°	°	°	°	°	°
Crank angle ...	0	30	60	90	120	150	180	210	240	270	300	330
Steam temps. by indicator	304	328	308	275	245	212	212	212	212	212	212	273
Steam temps. by Plat. therm. .	307	335	305	270	241	208	207	208	208	209	211	276
Wall temps. at 0·04 ins.	301·1	303·2	305·2	305·1	303·6	302·6	301·1	301·4	301·6	301·5	301·4	301·2

Mean temperature of steam, 246° Fahr.
Mean temperature of wall at 0·04 ins., 302° Fahr.
Range of wall temperature at 0·04 ins., 4·3° Fahr.

This range of 4·3° corresponds to a range of 7·2° at the surface, which corresponds to a heat absorption of 1·65 T.U. per sq. ft. per cycle, or to a condensation of 0·00184 lbs. of steam per sq. ft. per rev., and at 73 5 revolutions per minute, this is found to be equivalent to an initial condensation of about 8·8 lbs. per hour per sq. ft. of surface. As area of cylinder-wall exposed up to cut-off is 4·45 sq. ft., the total initial condensation is 39 lbs. per hour. The feed through steam chest was 456 lbs. per hour, and weight of steam accounted for by indicator was 131 lbs. per hour, so that there is a missing quantity of (456 – 131) = 325 lbs. per hour, only 39 lbs. of which can be put down to cylinder condensation. This 286 lbs. must have leaked across the valve-face from steam to exhaust. As the rate of leak is independent of speed or load on engine, it is evident that the proportion of loss by leakage will be much less at higher speeds and greater loads. Tests were made with an ordinary unbalanced and with a balanced slide-valve, both of which were steam-tight when stationary at the middle of their stroke. With the unbalanced valve, a leakage of 41 lbs. per hour was noticed with a pressure of 34 lbs. in the steam chest. With the balanced valve of the engine in question, which was fitted with a pressure relieving plate at the back, a leakage of 267 lbs. per hour was noticed with a pressure of 80·5 lbs. It is found that

$$w = c \frac{b P}{l}$$

Where w = weight of steam leaking per hour.
" c = constant = 0·02.
" b = perimeter of valve edge.
" l = average width of bearing surface of valve on steam chest face.
" P = pressure difference between steam chest and exhaust.

—**Prof. J. T. Nicholson, D.Sc., M.Ins.C.E.,** *Power, Vol. XXIV, No. 2,* pp. 19E–21E.—*A. H. G.*

The Use of Superheated Steam.

THE author gives a historical résumé of the uses of superheated steam from the time of Watt up to the present. He points out that the statement of the consumption by an engine of a certain number of pounds of superheated steam per h.p.-hr., does not give means for a true comparison between this engine and one using saturated steam. The comparison ought to be between the heat units converted into work in each case. The author believes in a high degree of superheat. If this is desired, it is necessary that the superheater coils be so placed that the hot gases will strike them long before they have been cooled sufficiently to allow them to escape into the chimney. If slight superheat is desired, the coils may be placed so that the gases, on leaving the boiler, strike the coils. Independent superheaters, with separate furnaces, may have the temperature of the superheat more conveniently adjusted, and have, when properly designed, invariably shown an economy. Steel tubes for superheaters have the advantage that the walls are thin, and being smaller than cast-iron pipes are usually made, the heating surface is, for both reasons, more effective. Cast-iron pipes, however, suffer less from the action of the heat. The difficulties due to the use of high temperatures in the engine cylinder, due to expansion and difficulty in lubrication, have now been surmounted, the development in design having followed the lines of the gas engine. In the author's opinion, both the double-acting gas engine and the double-acting engine for superheated steam will be the type of the future. Corliss valves are not adapted for the use of steam superheated by about 200 degs. Fahr., double-beat or drop valves being essential. Steam turbines will benefit, even more than the steam engine, by the use of superheated steam. The author gives the results of several tests of engines using superheated steam, made by Prof. Schroeter, which show a gain of economy of up to 26 per cent., due to the use of the superheater. The superheat in these tests ranged up to 340 degs. Fahr., and 218 i.h.p. were developed, with an equivalent saturated steam consumption of 10·01 lbs. per i.h.p.-hr., with 311 degs. Fahr. of superheat, the steam pressure being 145 lbs per sq. in. by the gauge, cylinders being 12¾ ins. and 22 ins. diam., and 32½ ins. stroke, running at 127 revolutions per minute. In the author's own experiment, with a boiler gauge pressure of 95 lbs. per sq. in., and with a compound engine developing 32 i.h.p., the cylinders being 8 ins. and 13 ins. diam., and stroke 20 ins., and the revolutions 92 per minute, the economy, based on B.T.U., given to the engine, varied from 6 per cent. with 57 degs. Fahr. of superheat, to 19 per cent. with 192 degs. Fahr. of superheat. Experimental results also show that the cut-off has very much less influence on the economy of an engine using superheated steam, than with saturated, there being, in one case, very little difference in economy between a cut-off of 16 per cent. and one of 48 per cent. Also the interchange of heat between the steam and cylinder walls is rapidly reduced with increased superheat, and to this fact is largely due the economy of superheating. Tests of a compound engine using steam at 100 lbs. gauge pressure, show that the amount of heat given to cylinder walls, with 156 degs. of superheat, is only one-fourth of that with saturated steam; with a triple expansion engine using steam at 138 lbs. gauge pressure, and with 140 degs. of superheat, tests show only about 20 per cent. of an interchange of heat in high-pressure cylinders. From the result of a large number of observations and reports, the author is of the opinion that the extra cost due to interest on cost of installation with depreciation, together with that due to the increased quantity of the best oil, which must be used, is greatly over balanced by the saving in coal in the great majority of cases. — **Prof. Storm Bull, M.W.S.E.,** *Paper read before the West. Soc. of Eng. Jnl., Vol. VIII, No. 6,* pp. 691–715.—*A. H. G.*

Some Performances of Boilers and Chain-Grate Stokers, with Suggestions for Improvement.

IN this test the author gives the results of tests made on a Babcock & Wilcox boiler and on two Heine boilers. The Babcock & Wilcox boiler was of the ordinary type, while the first Heine boiler was fitted with a furnace by enclosing the lowest set of water tubes in a casing of tiles to within 3 ft. of the back end of the tubes. The second Heine boiler only differed from the first in that a series of baffle plates was fitted in the path of the gases, so that the gases were forced to flow three times the length of the tubes before escaping. In the ordinary Heine boiler the gases flow diagonally from the back end of the lowest set of tubes to the front end of the top row of tubes. The boilers were fitted with Babcock & Wilcox chain-grate stokers, and were all of approximately the same size and power, the Heine boilers having a slight advantage in this respect. For greatest efficiency, the baffle plates should be arranged so that the area is reduced as the gases fall in temperature, the velocity of the gases over the tubes remaining constant. The addition of these baffles gave results equal to an economiser requiring a large investment and considerable expense for maintenance, an economy of 21·4 per cent. being obtained simply by their use. With chain-grate stokers, the author concludes, that, owing to the relative thinness of the fire at the back of the grate, air in excess generally finds its way through this part of the fire. With a boiler fitted with no fire-brick furnace, the products of combustion, together with the unburned

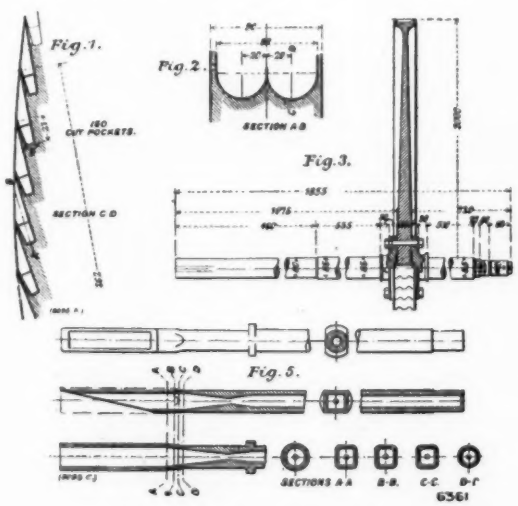
volatile matter driven off from the front of the grate, do not become mixed with this excess of air until their temperature has been reduced below that necessary for combustion. With a furnace, however, the temperature has not been reduced before the gases can mix, and consequently the volatile matter is not discharged unburned. The author advocates the working of chain-grate stokers with very thick fires, and with closed ash grates, to prevent excess of air as much as possible. In the experiments as high as 19·3 per cent. of CO_2 was obtained in the flue gases by doing this. The excess in efficiency of the furnace in the Heine boiler, due to the tile-brick roof furnace over the Babcock & Wilcox boiler, fitted only with fire grate and no furnace, was 8·86 per cent., the difference being due to more complete combustion. In the discussion on the paper, it was stated that a Babcock & Wilcox boiler, which had been provided with a furnace by casing the lower rows of tubes with fire-brick tiles and with baffle plates for causing the gases to flow along the tubes, the full length of the boiler, had had its efficiency greatly increased, though no quantitative results were given. — **A. Bement, M.W.S.E.,** *Jnl. Western Soc. Eng., Vol. IX, No. 1,* pp. 44–82.—*A. H. G.*

Gas-Power for Central Stations.

THE purpose of this paper is to establish the contention that modern gas-power machinery is suitable for central station service, and can be operated with far better economy and less running expenses than a steam plant; also, that gasworks labouring under low load or output factor can profitably install a gas-power electric generating plant and become its own largest customer, selling both gas and electricity at competitive rates. The data is drawn from fifteen light and power plants (using gas-engines as their principal motive power) in various parts of the United States, a number of them being operated in connection with illuminating-gas works. Twelve of these plants averaged 314 full load b.h.p. each. The other three were somewhat larger, averaging 568 b.h.p. The requirements that gas-engines must fulfil, and the advantages they offer, are fully discussed under a variety of heads, and numerous tables and curves of costs, etc., are given in illustration of the different points.— **J. R. Bibbins,** *Paper read before the Am.I.E.E., New York, Report Power, Vol. XXIV, No. 2,* pp. 100–109.—*E. J. W.*

The Riedler-Stumpf Steam Turbines.

PROFESSORS RIEDLER and STUMPF have, in the design of the turbine bearing their name, combined a gradation in steam pressure, with a gradation in steam velocity. The rotor diameter, too, has been largely increased, necessitating perfect materials of construction, and perfectly smooth wheels. The buckets are further milled out of the solid disc, which is made of 10 per cent. nickel steel. The centre of gravity of the rotor is brought within 0·01 mm. of the geometrical centre of the shaft, and the single bearing is brought as near as possible to the rotor. The nozzles, illustrated in Fig. 5, are made of nickel steel, which is not liable to rust. Figs. 1 to 5 give details of the rotor and nozzles of a 2,000 h.p. turbine installed at Moabit. The nozzles are united to an arc, and the rotor buckets not played upon by steam are covered to decrease the frictional resistance. The clearance between rotor and nozzle in this turbine is 3 mm. measured radially, and has been increased to 5 mm. without affecting the economy. This turbine runs at 3,000 revolutions, with steam at 188 lbs. per sq. in., at 562 degs. Fahr., and with a condenser vacuum of 25·5 ins. The rotor weighs only 1,875 lbs., so that two bearings suffice for turbine and generator-unit. When desired to apply the compounding principle to steam velocity, one of the constructions shown in Figs. 9 to 17 is used. The rotors can, with either construction, be inspected and taken out without touching the guide-blade rings. In compounding the pressure, each turbine may be sub-divided into a series of wheels separated by partitions which completely divide the casing, and the speed may thus be reduced to 500 revolutions. The table on the next page gives the steam consumption of the 2,000 h.p. machine previously referred to:



THE RIEDLER-STUMPF STEAM TURBINE.

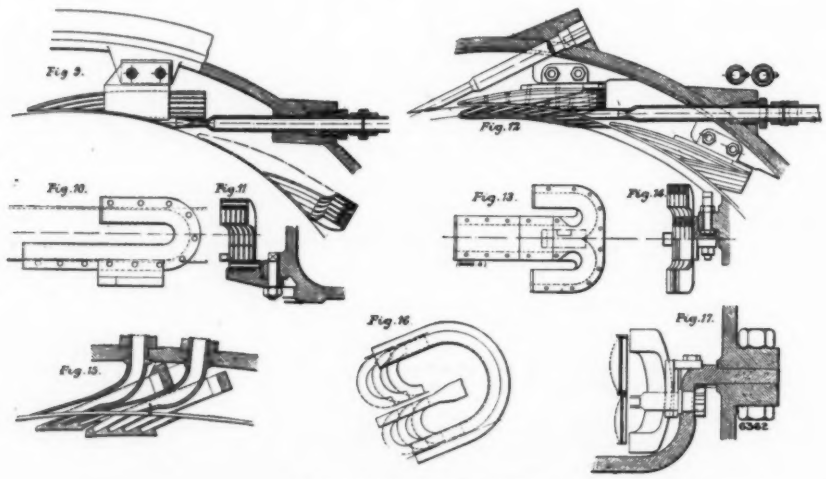
Date.	Load.		Pressure. lbs. per sq. in.	Temperature of Steam in Degs. Cent.	Vacuum in Inches of Mercury.	Steam Consumption.	
	Kilowatt.	%				Per kw.-hour in lbs.	Per e.h.p. per hour in lbs.
November 12, 1902 ...	850	57	113·6	298	27·6	20·75	15·2
November 13, 1902 ...	830	57	115·0	290	27·6	20·25	14·96
May 17, 1903	554	37	98·0	273	26·7	21·82	16·1
June 15, 1903	1365	—	128·0	294	25·5	19·6	14·35

Engineering, Vol. LXXVII, No. 1989, pp. 211–214.—*A. H. G.*

The Brush-Parsons Steam Turbine.

THE paper describes the construction of this turbine, and compares its advantages with those of the Rateau type. The weight of rotor of a 1,000-k.w. machine is 6,300 lbs., and the mean pressure per square inch on the bearings is 42 lbs. The surface velocity of journal is about 2,150 ft. per second, and multiplying mean surface speed by mean pressure, we get 90,350. Comparing these figures with those obtained in high-speed reciprocating engine work, we get pressure per square inch on bearings, 160 lbs.; surface velocity, 575 ft. per minute; and product of these numbers gives 92,000, or approximately the same as in the turbine. The author shows how the angles of the vanes and guide-blades affect the economy, and also how an increasing vacuum improves economy. The following comparison of the condensing plants, etc., required for reciprocity and turbine sets of 500 k.w. is interesting:—

	Reciprocator.	Turbine.
Consumption of steam per k.w.-hr. lbs. ...	25	22·5
Steam to be condensed per hour	12,500	11,250
Tube surface sq. ft. ...	1,050	1,540
Vacuum in condenser, ins.	26·5	28
Air-pump capacity, cub. ft. per min.	125	150
B. H. P. to drive air-pump	3·3	3·85
Circulating water, gals. per min.	730	830
B. H. P. to drive circulating pump	5·5	6·3
Temp. circulating water inlet	65° F.	65° F.
Temp. circulating water outlet	95° F.	90° F.
Mean temp. in condenser	119° F.	100° F.
Cost, prime mover and generator	£3,250	£3,250
Cost, condensing plant	£556	£659
Total cost	£3,806	£3,909



THE RIEDLER-STUMPF STEAM TURBINE

During the discussion the following table was given :—

	Turbine.	Reciprocating set.
Capacity	1,800 k.w.	1,800 k.w.
Speed	1,040 revs.	75 revs.
Steam consumption at full load ...	19·59 lbs.	19·83 lbs.
Vacuum	26·5 ins.	27·4 ins.
Steam press	125 lbs. saturated	156 lbs. saturated
Capital cost per k.w. – foundations, and including condensers ...	£8·3*s.*	£10
Cost of oil per unit	0·0018*d.*	0·006*d.*
Cost of generator brushes	0·0062*d.*	0·00005*d.*

The cost of brass wire brushes or tube generators outweighed the saving in oil. Using copper blades, superheat up to 800 degs. Fahr. may safely be used.—**William Chilton,** *Paper read before Manchester Local Section of Institute of Electrical Engineers, Electrician, Vol. LII, No. 19,* pp. 732–735.—*A. H. G.*

Heat of Generation of Superheated Steam.

Dr. E. Griessmann's experiments afford a confirmation of the hypothesis frequently put forward of late years that the heat of generation of superheated steam, as calculated from the usual equation :

$$i = 606{\cdot}5 + 0{\cdot}305t + 0{\cdot}48\,(T - t)$$

would be too small. The experiments further allow of conclusions being arrived at as to the behaviour of steam in the vicinity of the limit of condensation, as to which there are many divergent opinions. It is shown that at least in the neighbourhood of the limiting curve, *i.e.*, with low superheat, the specific volume of superheated steam should be determined from the Zeuner state equation.—**A. Griessmann,** *Zeitschr. d. Ver. Deutsch. Ing., Vol. XLVII, Nos. 51, 52,* pp. 1852–1858, 1880–1884.—*A. G.*

Concrete Foundation and Cement Filler for Brick Pavement.

About a year ago the writer made a series of experiments to determine the variation in the strength and cost of concrete due to a variation in the kind of cement and in the proportions of the ingredients. The tests are given in a table, and from this table the following conclusions are drawn :—(1) The cost of Portland cement concrete is about 4 per cent. more than natural cement concrete, while the former is 50 per cent. stronger. (2) The strength of concrete composed of 1 pt. natural cement, 3 pts. gravel, and 3 pts. broken stone, and concrete composed of 1 pt. Portland cement, 10 pts. gravel, and 10 pts. broken stone, are nearly equal. (3) The addition of broken stone in amount equal to the gravel, without increasing the quantity of cement, materially increases the strength and decreases the cost of the concrete. (4) The increase of the broken stone from 4 to 8, or from 8 to 16 pts., does not materially change the strength of the concrete, but reduces the cost. (5) About a half-mile of pavement having a very lean Portland concrete was laid down during the past season under the writer's direction, and it was found not only that the very lean concrete was more easily mixed, but that it was more uniform than the very rich natural cement concrete. In all respects the Portland cement concrete was superior to the natural cement concrete. The writer made a number of brick beams by taking paving brick and cementing them together with a cement filler. The beams were 3 bricks long, 3 bricks wide, and 4 ins. deep ; and were formed by laying the bricks side by side as in the pavement, and the interstices were filled with grout, consisting of 1 pt. Portland cement and 1 pt. sand. The filler cost 8 to 12 cents per square yard. By comparing the tests given in a second table with those given in the first, the writer finds that a brick beam 4 ins. in depth is 50 per cent. stronger than a concrete beam consisting of 1 pt. natural cement, 3 pts. gravel, and 3 pts. broken stone, and is also a little stronger than a beam consisting of 1 pt. Portland cement, 8 pts. gravel, and 8 pts. broken stone. This fact suggests the question whether it may not be more economical to employ the cement as a filler between the bricks, rather than to use it in the concrete foundation. The cost of the cement and labour for a 6-in. layer of concrete, composed of 1 pt. Portland cement, 8 pts. gravel, and 8 pts. broken stone, is about 24 cents per square yard more than that of a compacted layer of gravel or broken stone ; and the cost of cement filler is about 6 to 10 cents per square yard more than sand filler. Therefore a brick pavement with cement filler on a foundation of broken stone or gravel without any cement in it is from 14 to 18 cents per square yard cheaper than brick pavement with sand filler and with a concrete foundation ; and further the two forms of construction are of equal strength. —**O. L. Gearheart,** *Proc. Illinois Soc. C.E. and Surv., Rept. Eng. Rec., Vol. XLIX, No. 7,* pp. 189–191.

Ferroinclave : A Fireproof Building Material.

This paper describes a new fireproof material named "ferroinclave," and consisting of a specially corrugated steel sheet covered with cement-mortar, or concrete. Fig. 1 represents a section of ferroinclave roofing, which is coated with concrete to the thickness used in the majority of roof constructions. Reinforced concrete piles may be made by joining end to end a number of ferroinclave sheets, bending them into a pipe shape and concreting

FIG. 1.—FERROINCLAVE.

them inside and out, so as to form a solid cylinder. These piles are of great value because of their indestructibility. Figs. 2 and 3 show the results of a series of tests made upon No. 24 ferroinclave sheets, 20 ins. wide by 10 ft. long, placed upon two spans of 4 ft. 10½ ins. each, and coated on the top with the various thicknesses of concrete, which are given as the ordinates of these curves. Figuring from these tests, we see that, when a ferroinclave roof is made 1¼ ins. thick, and placed upon a span of 4 ft. 10½ ins., it will support a uniformly distributed load of 50 lbs. per sq. ft., with a factor of safety of six. In a simple fire test described by the author, a slab of ferroinclave roofing was loaded to about 50 lbs. per sq. ft., and placed upon two spans of 4 ft. 10½ ins. each. Fire and water were then alternately concentrated upon these sheets for about an hour, without doing any injury except to sag them very slightly. A ferroinclave roof, when made only 1¼ ins. thick, will conduct heat about $\frac{1}{70}$th as fast as corrugated iron, and about six times as fast as 2-in. planks. The cost of a ferroinclave roof, complete, varies from 20 dols. per square of 100 sq. ft., up to 26 dols. per square when made 1¼ ins. thick. The average ferroinclave floor costs little more than the roof. Ferroinclave walls cost from 22 dols. up to 35 dols. per square, depending upon locality, height, etc. —**H. F. Cobb, Assoc.Eng.Soc.,** *Vol. XXXII, No. 1*, pp. 1–10.

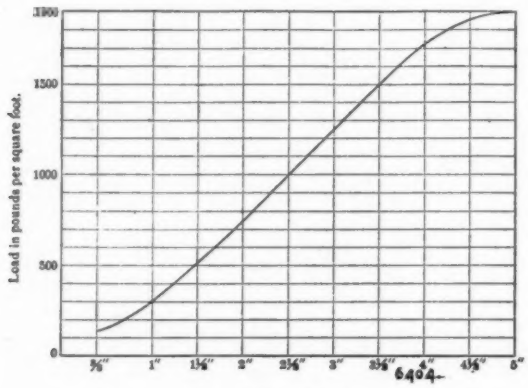


FIG. 2.—FERROINCLAVE.

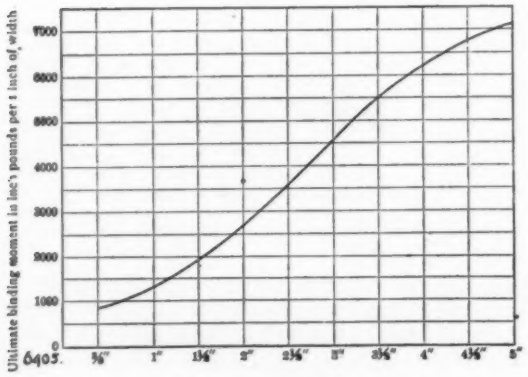


FIG. 3.—FERROINCLAVE.

The Graphical Calculation of Flange Stresses in Girders and Trusses.

HAVING recently had charge of the reinforcement of the lines of the Manhattan Railway Co., New York, the writer had to deal with such an enormous amount of figures for calculating the longitudinal and cross girders under different loadings, that he endeavoured to reduce the manner of obtaining stresses to a more systematical method. He started to work out a method by which all girders of different lengths and depths were figured with one diagram, for one kind of loading. The result was not only to reduce calculation, but to succeed in getting records of all important calculations by graphics. The diagram reproduced (Fig. 1) shows the effect of the longitudinal girders on the cross girders; it is simply the application of well-known graphical principles. This loading is such that it will give the maximum reaction when one of the heavier wheel-loads will be over the floor-beam. To show the process of getting the flange-stresses in girders and trusses, the writer gives a diagram (Fig. 2) which was made for two 188·5 tons engines, followed by 5,000 lbs. per lineal foot of track. This diagram can be used with great accuracy for the calculation of spans, varying from 30 ft. to 250 ft., always assumng the same loading; should, however, any uniform load precede the wheel-loads, this would be taken care of by a very simple construction of a parabola, using simply the last line of the equilibrium polygon next to the load No. 1 as the tangent. There is one feature in this diagram which enables one to use the maximum moment ordinate directly, to determine the flange stresses of any girder or truss, and of any span or depth. As shown in the diagram, we can obtain an equation which gives a value of the angle a, expressed as a function of the depth of h of the girder or truss to be calculated and the pole-distance H; this value being tan. $a = \frac{h}{H}$; the values of h and H measured in the

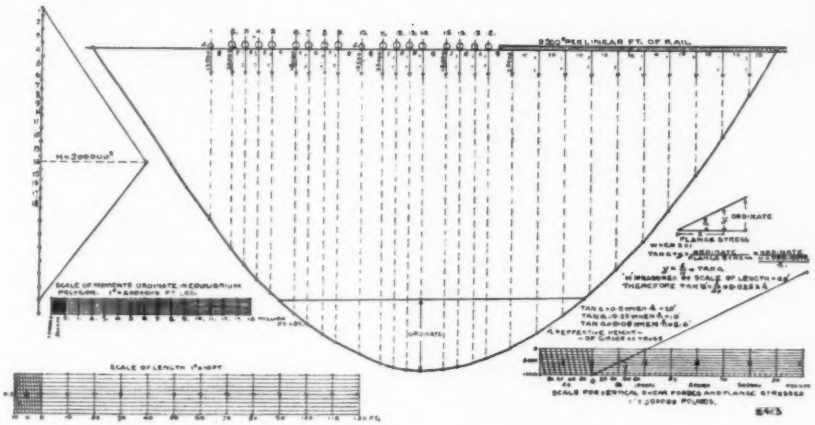


FIG. 1.

scale of lengths. This equation gives a straight line, of which any ordinate will give, in the abscissa, the value of the flange stresses. The operation of thus calculating flange stresses is as follows:—(1) Plot the polygons of forces and equilibrium to any convenient scale, according to principles of graphic statics. (2) Prepare on tracing-cloth an outline diagram of the girder or truss to the same scale as that of the lengths in the polygon of equilibrium; draw perpendicular lines through sections of girder or truss where it is desired to determine the maximum moments. (3) Find the position of wheels which will give the maximum moment. (4) Where vertical lines at the two extreme ends of girders or trusses intersect the equilibrium polygon, draw through these points the closing line and the ordinate under the section in question will determine the flange stress. (5) Lay out the scale used for the forces, making it a diagonal scale to get closer results. (6) Construct the angle a as function of h, the effective depth of girder, and H the pole distance. (7) Take the ordinate as found in (4) in the dividers; where this vertical distance will strike the two sides of the angle a, read off on the horizontal side the amount of flange stress.—**Oscar Sanne,** *Jnl. Western Soc. Eng., Vol. IX, No. 1,* pp. 34–37.

New Drawbridge over Newark Bay, New Jersey.

A DRAWBRIDGE of unusual design has recently been erected under difficult conditions on the Newark Bay crossing of the Central Railway of New Jersey, and the structure is near the eastern end of a two-mile trestle crossing the lower end of the bay. The existing swing-bridge, built in 1887, has long been too light for the traffic, and about three years ago it was decided to replace it by a bridge designed for modern engine and train loading. The engineers of the company decided upon the Scherzer rolling-lift type for the new bridge, on account of the facility thereby offered for erection with minimum interference to traffic, and also with a view to later widening to four-track. In this form of bridge no centre pier is required, so that the draw-span forms only one channel, as against the two channels formed by a swing-bridge; but the shipping interests concerned in the Newark Bay channel insisted that two separate channels should be provided in the new drawbridge. This led to the arrangement shown in the diagrammatic elevation here reproduced. Two Scherzer double-track through spans, each 120 ft. centre to centre of piers, but giving a net width of channel of only 85 ft., are arranged back to back, separated only far enough to allow of placing the operating-house between them. Both spans are operated from this house

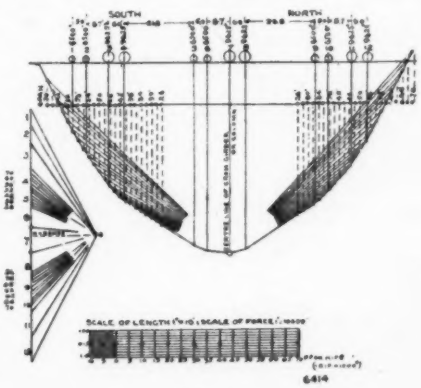
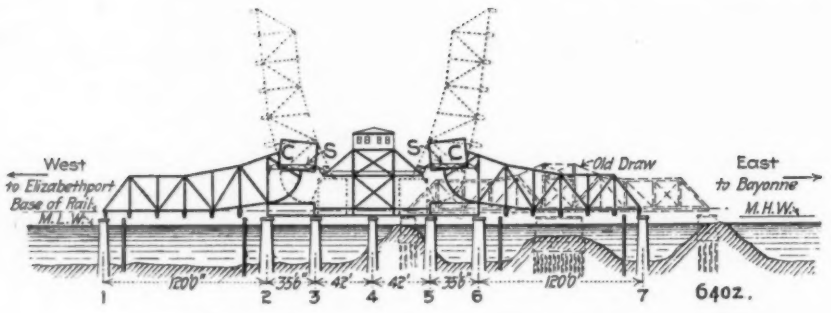


FIG. 2.



NEW DRAWBRIDGE OVER NEWARK BAY, NEW JERSEY.

by separate sets of gearing, which may be connected to a main jack-shaft for either forward or reverse operation. Two separate engines are provided, each of which is capable of operating either or both spans. A noteworthy feature of this bridge is that it is operated by two 75-h.p. gasoline engines, set on opposite sides of the machinery-house, in line of a common jack-shaft, to which both engines connect by friction couplings, this being the only part of the operating equipment that is common to both spans. The western half of the work was first taken in hand. The four westerly piers, Nos. 1 to 4 in the Figure, were built under the existing trestle-work to the west of the old draw. The main stringers and segment track were placed on these piers, and the west span was then built in the raised position, vertically in the air (see broken lines in the Figure). Floorbeams and stringers were put in position in the bridge, ready for the track. The bracing at the heel and between the counter-weights was left out until the time of lowering the span, when it was bolted in place in a few hours. Meanwhile the operating-house had been built and the machinery placed ready for operation. The operating-strut *S* being put in gear with its pinion, the span was successfully lowered into horizontal position after the trestle occupying the channel of this span had been removed. As may be seen from the diagram, the east span of the new bridge crosses the existing navigation channel centrally with the old swing-bridge. The line is double-track, and the two lift-spans, 120 ft. in span and trusses spaced 29 ft. apart, are correspondingly heavy. Roughly, the complete twin-bridge weighs 2,000 tons, about half of which is in the cast-iron counter-weights, *C* in the diagram. The operating-house has a rather short base, and carries a heavy cantilever-frame at each end, on which the operating or rack pinion and its gear train are located. This gear train is driven from the main jack-shaft by an inclined bevel-gear shaft. The new bridge is supported by solid concrete piers extending down to bottom, and there resting on piles driven to rock. The foundation piles were driven through the trestle, on one side at a time, and were cut off at a level of the bottom, at a depth which varied for the different piers from 32 ft. to 37 ft. For the construction of the piers the floating coffer-dam method was employed. The coffer-dams, built with removable sides, were floated out to the site, and the concreting of the piers begun inside them. When sunk far enough to go under the trestle each coffer-dam was pulled into place, guided by suitably driven piling, and by the admission of water was sunk to bearing on the foundation piles. The concreting was then completed, and the sides of the coffer-dams removed. The piers are of concrete to the top, without steel reinforcement except that a grillage of I-beams is moulded in place in the top to form the bridge seats.— **Anon.,** *Eng. News, Vol. LI, No. 8,* pp. 173–175.

Modern Workshop Design.

AFTER generally discussing modern workshop construction in Canada, the author describes various forms of flooring. The following is a description of a floor which he believes to be one of the most durable and economical. It consists of a 3-in. cinder ground, well tamped to receive a 3-in. tar-and-cinder foundation rolled level, over which is laid a hot vulcanite composition 1 in. thick, into which are bedded 3-in. planks. The planking is covered with two-ply tarred felt, over which is laid a 1-in. matched hardwood flooring. The author has found the layer of tarred felt between the upper and lower planking makes the floor dust, water, and oil proof. The paper concludes with some references to plant for handling coal and raw materials. — **A. Pringle,** *Proc. Can. Soc. C.E.*, pp. 1–12.

The Single-phase Railway System of the Union Electricity Company, Berlin.

THE only motors capable of being used for railway traction purposes are those which are free from the drawbacks characteristic of rotary-current motors. The use of single-phase collector motors, while satisfying this condition, was so far quite out of the question on account, in the first place, of the bad working of the collector. The Union Electricity

Company, Berlin, on the patented devices and researches of the author in conjunction with Mr. G. Winter, have developed a single-phase collector motor corresponding in every respect to the requirements of railway motors. This motor is being used in connection with the trial runs begun in August, 1903, on the Niederschönweide Johannisthal-Spindlersfeld suburban line, near Berlin. The current is supplied at a tension of 6,000 volts and at 25 periods from the Oberspree Electricity Works of the Company. The rails, being earthed, are used as return; and though one pole in the power-station and on the track is earthed, a return cable to the power-station has been provided. The trial track is 4·1 km. in length; there are no appreciable gradients, but some curves about 300 m. in radius. The running-wire is suspended from one or two longitudinal steel wires, at distances apart of about 3 m., so as to exclude nearly completely any tension in the working-wire, and to diminish the danger of a rupture, the consequences of which are, moreover, materially diminished, as the end of a broken wire remains beyond the reach of the *personnel*. As the longitudinal wires are not insulated from the running wire, they participate in the conduction of current. Even in the case of the wire being broken the supply of current will therefore not be interrupted. The longitudinal wires have a double insulation against earth, being suspended by means of insulating loops from iron transversal bearers, which in turn are fixed to high-tension porcelain insulators, the shaft of which is surrounded by india-rubber. As regards the two cars used on the experimental track, each has a weight of about 52 tons, including the electric equipment of about 6 tons in weight; there are two trucks and two motors fixed to either of these, and driving the axles by means of toothed wheels. The ratio of the toothed wheels is 1:4·26, and the running wheel diameter 1 m. In cases of emergency the direction of the cars may be reversed by means of back-current. The motor includes a stator similar to those of ordinary induction motors, containing a single-phase coil arranged in notches, and a collector armature designed like the armature of a direct-current motor, and to which two sets of brushes with axes perpendicular to one another are fixed. The first set, the axis of which coincides with the axis of the stator coil, is short-circuited, carrying the working currents proper which are induced by the field ϕ in the direction of the axis of the stator coil, while the other set of brushes is located on the secondary coil of a series transformer inserted in the main current circuit, carrying only magnetising currents, which produce a transversal field F perpendicular to the above field, by which, in conjunction with the stator current, the efficient torque is produced. The presence of two separated fields enables the motor to work without sparking. The e.m.f. generated is a winding short-circuited by a brush through the induction of the field F, is perfectly compensated with increasing numbers of revolutions by the e.m.f. due to the rotation in the second field ϕ, which is impossible in the case of monophase series motors, where, in the winding short-circuited through a brush an electro-motive force independent of the number of turns, and incapable of being compensated, is induced. Moreover, by the rotation of the armature an e.m.f. is induced in the exciting circuit of the armature, which is able not only perfectly to compensate the e.m.f. of self-induction of the circuit, but at the same time the e.m.f. corresponding to the primary and secondary leakage. The power factor will thus, with increasing numbers of revolutions, approach the value $\cos \phi = 1$, this value being maintained constant within wide limits, on account of the singular regulation. Without any prejudice to the motors, the air-gap may therefore be made as great as in the case of direct-current motors, and open-stator notches used instead of closed notches. The ratio of the exciting transformer is regulated by the insertion or disconnection of windings. In the case of the series transformer being adjusted for a given ratio, the motor will behave in a way quite similar to a direct-current series motor, both the current intensity and the torque having the maximum value at rest, and decreasing for increasing angular speeds. In the case of the ratio of the series transformer being diminished the characteristic curve of the motor is displaced, so as to give the same torque as previously observed with a given number of revolutions M_1 appear only at a number of revolutions M_2 (superior to M_1). The same number of revolutions will now correspond with a higher torque than before, the torque at rest being evidently also higher. The motor is started by altering the ratio of the regulating transformer, the current of the exciter brushes being interrupted at rest, when the primary coil of the series transformer will act as a reaction coil, the whole motor being traversed only by a very small current. It will thus be unnecessary to open the primary coil of the motor when stopping, it being sufficient to open the exciting circuit (low-tension coil) as the motor works only in the case of the exciting circuit being closed. The motors of the Spindlersfeld cars have an output of about 100 h.p.-hrs.; they have four poles and a monolateral air-gap of 3 mm. The total weight of a motor, including the small-toothed wheel, is 2,140 kg., the weight of the exciting current transformers common to both motors being 1,100 kg. As regards the arrangement of the connections, the direct-current multiple unit system of the Union Elecktricitäts Ges. has been used and slightly modified. Two cars are being run in addition to three trailers, each 16 tons in weight. The cars are designed for a maximum speed of 40 km. per hour, though speeds as high as 60 km. are sometimes reached. The motors have given full satisfaction even in the case of the highest strains, the whole train, including two motors and three trailers (155 tons), being often arranged and driven by the two motors only. The perfect independence with respect to the line tension has proved a special advantage as compared with the rotary-current system, two-thirds of the line tension having been sufficient to maintain the regular service, while starting and running at a speed of about 30 km.

was possible with 40 per cent. of the motor tension.—**F. Eichberg,** *Zeitschr. des Vereins Deut. Ingen., Vol.XL VIII, No. 9,* pp. 303–308. —*A. G.*

Continuous Current v. Induction Motors.

THIS paper consists of an elaborate comparison between specific designs of continuous-current and induction motors, primarily with a view to determining how the rated speeds affect the type that should be employed. For this purpose all the chief details of design, together with illustrations showing the principal dimensions and curves of efficiency, power-factor, etc., are given for the following eleven 150-h.p. motors:—Five continuous current shunt machines, ranging in rated speeds from 68 to 1,224 revolutions per minute; three 21-cycle induction motors, ranging from 36 poles and 68 revolutions per minute to 4 poles and 612 revolutions per minute; and three 63-cycle motors, ranging from 12 poles and 612 revolutions per minute to 6 poles and 1,224 revolutions per minute. The curves in Fig. 1 show the approximate relative factory costs of these designs. They are derived from the formula $K \times D \times L$, where K is a constant, D the diameter of the armature or rotor in centimetres, and L the length over armature or rotor windings in centimetres. The author considers that in continuous-current machines 1 shilling may be taken as a rough value for K, and that the corresponding figure for induction motors will be 0·67 shilling, rising to 0·75 shilling if with wound rotors, and falling to 0·60 shilling for squirrel-cage rotors. A second method of determining total factory costs, which leads to closely similar results, is also given, based on a calculation of the cost of effective and non-effective material independently of each other. Fig. 2 affords a comparison of the full and half-load efficiencies of the machines, from which it will be seen that those of the continuous-current motors are lower for the higher speeds, those of the induction motors starting very low, but increasing rapidly with speed. Other curves for power-factor, reactance voltage, etc., go to show that all the properties of induction motors improve markedly with speed, whereas the reverse is the case with continuous-current motors. Finally, the four following conclusions are drawn from the data contained in the paper:—(1) Induction motors are, for all capacities, considerably cheaper than continuous-current motors of equivalent ratings. (2) The general performance and mechanical construction of induction motors improve rapidly with increasing rated speeds. (3) The general performance and mechanical construction of continuous-current motors improve rapidly with decreasing rated speeds. (4) The use of very low-speed induction motors and very high-speed continuous-current motors ought to be avoided whenever this is commercially practicable. — **H. M. Hobart,** *Paper read before the I.E.E., London.* —*E. J. W.*

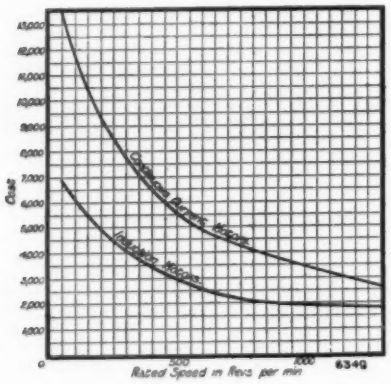


FIG. 1.—CONTINUOUS CURRENT *v.* INDUCTION MOTORS.

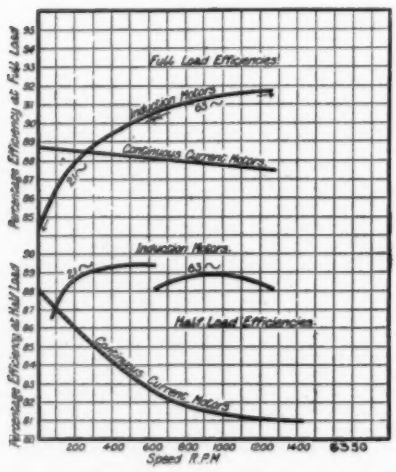


FIG. 2.—CONTINUOUS CURRENT *v.* INDUCTION MOTORS.

Continuous-Current Pulsations of Rotary Transformers.

MANY recent researches go to show that the direct-current derived from a rotary converter is of a pulsatory character. While different explanations have been suggested for this phenomenon, the author shows these pulsations to be mainly due to the superposition of the ohmic tension-fall for direct- and alternating-currents within the armature, any other cause of pulsation being of a distinctly secondary character. The number of periods of the alternating tension, superposed on the direct-current tension, is, in the case of the monophase transformer, twice; and with three-phase and six-phase transformers, six times the value, corresponding to the alternating-current supplied. The individual pulsating-current waves

are composed of sinoidal waves similar to the pulsations of a direct-current machine with a very small number of collector segments, sharp angles being formed on the lower flexion point of the curve. In the case of polyphase transformers, the tension-fall is always positive, being equivalent to a fraction of the ohmic tension-fall of the same direct-current machine, the total difference of the pulsating-tension being small. With monophase transformers the ohmic tension-fall, in the course of each period of the armature, takes twice negative values, thus acting as an increase in tension. The difference between the maximum and minimum values of the tension is a multiple of the ohmic-fall in tension which the transformer would undergo as a direct-current machine. The amplitude of pulsation is shown to depend on the load and on the shape of the poles of the transformer. In the case of the direct-current circuit being opened (the load being *nil*), there is always a pulsating increase in tension, the period of pulsation being the same as in the case of the circuit working under load. With monophase transformers the increase in tension varies between zero and a value approaching or exceeding the fall of tension of a direct-current machine, according to the shape of the poles; in the case of polyphase transformers, this increase in tension is always positive, while being inferior to the figure observed with the direct-current machines. The e.m.f. of the transformer cannot therefore be determined from the tension at the terminals in the case of the direct-current circuit being open. The superposition is even manifested on the alternating-current side, resulting in a strong diminution of the ohmic tension-fall, in addition to a deformation of the tension-curve. This deformation, being very small with monophase transformers, is shown rapidly to increase with the number of phases. The phase and number of periods of the fall in tension on the alternating-current side are identical to those of the alternating-current. A difference of phase between the current and the e.m.f. is shown to influence the direct-current only with considerable values of this difference, while this influence is much more marked on the side of the alternating-current, the decrease in tension of this side reacting on the direct-current side in the case of a constant-current output. The author accounts for the great departures in the results obtained by other experimenters on the differences in the design of the machines used.—**R. Elsässer,** *Elektrotechn. Zeitschr., Vol. XXV, No. 9,* pp. 163-167.—*A. G.*

Alternating-Current Rectifiers.

THE function of the rectifier is to redress alternating current by inverting one-half of the current wave, so as to give it a uni-directional pulsating nature. Excluding rotary converters, which are not rectifiers in the commonly accepted meaning of the term, they are of three kinds, mechanical, vapour, and electrolytic. The first of these comprises synchronously-driven rotating or vibrating reversing switches, which are far cheaper than rotary converters; but the impossibility of suppressing the destructive sparking that goes on has prevented them from receiving any extensive application. The two latter kinds are based upon the property which certain substances possess of offering only a low resistance to current flowing in one direction, but very great opposition when it attempts to pass in the other. Mercury vapour exhibits this characteristic in a most marked degree, and it has been utilised by Cooper Hewitt in constructing a rectifier which is remarkable for the large amount of energy it can deal with per unit of weight and volume, and also for an efficiency exceeding 98 per cent. Aluminum immersed in certain liquids behaves in the same way, and constitutes the electrolytic rectifier. Tests made by the author upon various types of such rectifiers employing aqueous solutions show that the best of them do not operate at an efficiency exceeding 50 to 60 per cent. under practical conditions, and a marked decrease results if the temperature be allowed to rise beyond 30 to 40 degs. Cent., so it is necessary for rectifiers of any size to be kept cool by some air or water-circulating apparatus. Carl Hambuechen has discovered that aluminum acts most successfully as a rectifier in an electrolyte of molten sodium nitrate, and works at an efficiency of 10 to 30 per cent. greater than in aqueous solutions. It has the further advantage that the heat generated is usefully employed in keeping the electrolyte in a fluid state. A rectifier with aluminum and iron electrodes, the former 2 by 1 by $\frac{1}{8}$ in. in size, will carry a normal load of 10 amp. at an e.m.f. of 25 to 30 volts rectified. The current may exceed this value by several hundred per cent. for a short time, and a 50-per cent. overload only causes excessive heating and vaporisation of the electrolyte after several hours run. A small amount of salt has to be added once in each day's working to compensate for ordinary losses of this kind. The total weight for an output as above is about 30 lbs., and most of this is due to the special transformer required. To start the rectifier from the cold and solid state, a large volume of low-voltage alternating current is drawn from the transformer and passed lengthways through the iron electrode for a few minutes, after which it is switched off.—**Charles F. Burgess,** *Paper read before the North-western Elec. Assn., Milwaukee, Report Elec. Rev., N.Y., Vol. XLIV., No. 9,* pp. 319, 320.—*E. J. W.*

Electrical Driving.

FROM tests taken in a number of mechanically-driven factories, particulars of which are given in tabulated form, the author arrives at the conclusion that, on an average, 55 per cent. of the indicated h.p. is effectively delivered to the machines. For a system of electrical distribution he calculated a corresponding efficiency of 60 per cent., assuming engine, dynamo, and motors to be working at $\frac{3}{4}$-load, and that one-third of the power is applied to group-driving. Taking the case of an engine indicating 100 h.p. at $\frac{3}{4}$-load, the following comparison is made:—

	Full load.	¾-load.	½-load.
Indicated h.p. of engine ...	133	100	67
Electrical h.p. at motor terminals	109	80	50
Brake h.p. at motor shaft ...	90	62	36
Effective h.p. applied to machines	82	54	28
As compared with result of mechanical transmission ...	76	43	10

leaving a margin in favour of electricity of 6 h.p. at full-load, 11 h.p. at ¾-load, and 18 h.p. at ½-load. Group-driving cannot, as a general rule, be as efficient as individual driving; but it is now recognised that where machines are in constant use and below a given horse-power—say 5 h.p.—grouping is most desirable. It enables one motor to be employed of much less power than the aggregate of a number of separate smaller motors, because the former only has to deal with the average working load of the group, whereas each of the latter has to be equal to its own maximum load. — **B. Longbottom,** *Paper read before the Manch. Assoc. of Engrs., March, 1904.—E. J. W.*

Shipyard Economies. —Contd.

TURNING to organisation, it is absolutely essential that there be a well thought-out system for the preparation and transmission of plans, lists, and other information to superintendents, foremen, and workmen. A working understanding with owners' representatives will be best established by arranging that all plans and information be presented to the owners' representative for approval and signature by the chief draughtsman, after which the builders should not be asked for any deviation without an extra order. Notice should be given to the builders of any special requirements, tests, or the like to be carried out. There should be a responsible member of the builders' staff to receive and attend to any complaints made by the owners' representative, but no interference by the former with foremen or employees should be permitted or attempted. The owners should supply complete specifications and plans, so that in the first instance a proper basis may be supplied for the builder's estimate; and, secondarily, to avoid misunderstandings and mistakes during the course of construction. Systematic preparation and storage of fitting out details will result in considerable saving, if properly attended to. Harmonious working is much facilitated by a clear understanding of the scope of operations of various departments. It has been difficult in America to adopt any system of standardisation and specialisation on account of the varied calls made on builders; but in Great Britain the effect of this on the construction of tramp steamers has been to considerably reduce the cost of production. In addition to this, the effect, in the long run, is very much to the advantage of the ships, as the workmen become more accustomed to the special class of work, and can, from the experience gained, turn out the work quicker, more economically, and of a higher class. Attention is next directed somewhat fully to the arrangement of the buildings and yard. The advantages gained from the use of power-driven portable tools are discussed. An example of the saving by the adoption of pneumatic riveters in the place of hand labour is cited, the net result being that the total cost per rivet, excluding counting and testing, was, in a given instance, reduced from ·035 dols. in the case of hand labour to ·022 dols. with a pneumatic riveter. The final section of the paper deals with "Materials." Much of the success of shipbuilding depends upon the prompt and well-timed delivery of material so that the efficient working of the purchasing agents' departments possesses great importance. The secret of satisfactory delivery depends in a great measure upon the requisitions being made in good time, and upon judicious placing of the orders. Labour can be saved in the store department by good arrangements, and convenient weighing and lifting apparatus; but the greatest economies result from an organisation which keeps perfect account of stock, and produces it promptly on demand. Steel and iron-yard organisation should receive the closest attention. All material should be carefully stacked in order that it may be got at when wanted without undue loss of time caused in turning over plates, etc. A stock book should be kept by the iron measurer, and daily account kept of all receipts and issues. A correspondence book should be kept in the drawing-room, daily changes *visèd* and signed for by the chief draughtsman, and new orders of material for stock checked by comparison with the sizes at present in hand. In conclusion, it may be remarked that shipbuilding being an industry full of multifarious detail, economy is the result of attention to small things rather than to the broad generalisations of design and detail. If the work were always done correctly at the first attempt, shipbuilding could be made to pay without regard to "trash about details"; but, human nature being as it is, the patient and laborious qualities succeed in shipbuilding where superficial brilliance ignominiously fails. — **R. S. Hubbard,** *Marine Eng., Vol. IX, No. 2,* pp. 56–61.—*H. B. D.*

Submarine Boats.

LIEUT. JOHN HALLIGAN, of the U. S. Navy, has placed his views before the Navy Department, after making a study of the submarine problem. He maintains that the submarine is superior to the battleship, and that the principal quality of the submarine, that of submergence and invisibility, gives the best protection against attack. The present stage of submarine development, with the automobile torpedo, is such that when the boat is submerged and within torpedo-range, it must be admitted that the disablement or destruction of the battleship is probable, the degree of probability and the amount of damage depending principally upon the number of torpedoes that can be discharged by the submarine, and on her facilities for locating and estimating the range of the target.

Thus the submarine, with the above limitations, is eminently successful. Considering the varying conditions of distance, state of sea and weather, as well as the probable speed and course of a watchful enemy, the power of placing the submarine well within torpedo-range constitutes by far the most important factor in the problem. Inasmuch as the different types may be supposed to be armed with the same efficient and trustworthy type of torpedo, and as the daring and skill of the *personnel* may be equal for all types, it is seen that the true measure of efficiency of any submarine boat is the ability successfully to place itself within torpedo-range of the enemy.—*Steamship, Vol. XV, No. 176*, p. 309.—*H. B. D.*

Recent Developments in Cargo and Intermediate Steamers.

THE paper covers more particularly the period since 1899, in which year the author presented a brief note on the subject to the Engineering Conference. The same arrangement of the subject has been followed as in that note, namely, under the heads of—I. Type; II. Size; III. Construction; IV. Capacity; V. Cargo appliances; VI. Ballasting; VII. Economy of working. I. *Type.*—The "shelter decker" is still in favour for special service, and the design of the "single decker" has developed in the production of holds clear of beams and pillars, having a great advantage, especially in the carrying of such cargoes as coal, grain, etc. Tank vessels adapted not only for conveying oil in bulk but also for carrying ordinary cargoes are now largely used. The demands of the fruit-carrying trade have brought forth a special class of steamer fitted with refrigerating plants, and, notably those trading to the West Indies, are very successful II. *Size.*—Here depth of water in ports, docking facilities, etc., control development, but nevertheless great advance has been made. Comparative tables given in the paper show the number of ships of over 3,000 tons register under construction in the periods 1896-99 and 1900-1903 to be 718. These tables indicate a marked increase in size, especially from 7,000 tons and upwards. British superiority in the matter of shipbuilding is remarkable, in spite of keen competition. During the last four years, in the matter of large ships, the British numerical output increased 37 per cent., tonnage 59 per cent., and average size 16 per cent. on the previous four years. America and Germany have developed the shipbuilding industry immensely of late years. III. *Construction.*—The new features noticeable about five years ago are still largely in evidence, such as the flanging of internal work, joggling of frame bottoms and girder framing, whilst the stiffening of watertight bulkheads is more rationally arranged. Continuous hatch-coamings, not extended below the deck level, have been introduced. The flanging of the tank side to the shell and the extension of it up the bilge past the level of the bilge keel, has been an improvement. In one case, the practice usual in men-of-war has been followed, the tank side being extended to the lower hold-stringer, resulting in more space for water-ballast and in increased safety. IV. *Capacity.*—Vessels of 12,200 tons dead-weight and a measurement capacity of about 20,000 tons, at 40 cub. ft. per ton, have been very successful. These carry passengers as well as cargo, and have proved exceptionally comfortable. An interesting cargo manifest of a large intermediate liner, appended to the paper, shows 231,300 items and a weight of 9,260 tons. Another vessel carried 39,433 barrels of apples, weighing 2,960 tons, besides 71,000 bushels of wheat, and other miscellaneous cargo. Colliers of 7,000 tons, ore-carriers of 10,000, and "tankers" of even greater capacity indicate great industrial activity and progress. V. *Cargo-appliances.*—Speedy loading and unloading is of the utmost importance, and therefore special attention has been paid to this matter. Winches are more numerous and are run at higher speeds, manilla and small steel-wire runners are used; more derricks are fitted; and the hatchways are larger. Steel hatch-covers, hinged to coamings with patent fastenings, are now used, and do away with the beams. As an example of what a modern cargo-steamer can accomplish, mention is made of a vessel of 6,000 tons dead-weight, which made 36 voyages of some 55,000 miles in 11 months and 19 days, loading, carrying and discharging a total of 210,600 tons. The "turret" class have been markedly successful. One vessel, the *Grängesberg*, with 12 large hatchways and 24 derricks, worked by 12 double-ended winches, has discharged 10,000 tons of ore in 35 hours. Temperley transporters are largely used, but without grabs. There is ample room for suitable electric winches for this class of work. VI. *Ballasting.*—Increasing need for making half the passages in ballast and bunkers only have called for more attention to ballast-tanks. The adoption of high wing-tanks for about half-length amidships has been tried with success, giving a metacentric height of 3 ft. 9 ins. in one case. Similar has been the result of McGlashan's system of making a double skin as high as the upper deck, for about half the vessel's length amidships. The plan of carrying the water in special 'tween-deck tanks demands the increase of scantlings, which somewhat diminishes the advantages, but this is less costly than the building of deep tanks. Deep tanks in addition to a double bottom is the usual arrangement, but is only suitable for vessels making long voyages. Some boats with longitudinal centre-line bulkheads omitted in tanks of 27 ft., holding 1,400 to 1,500 tons of water, have been very satisfactory, being able to discharge this huge volume of water in about five hours. Careful distribution of weights has reduced the strain to a minimum. VII. *Economy of Working.*—The design of a vessel vitally affects the consumption of fuel. Vessels of 20,500 tons, making 15½ knots, on a consumption of 140 tons of coal per day; of 19,000 tons, at 15 knots, on 115 tons; of 11,600 tons, at 11·35 knots, on about 46 tons, are a few instances of what has been accomplished in the way of economical running. Careful comparison of the costs of land and sea conveyance gives remarkable results. In fact, taking 1·54*d.* per ton per geographical mile as the cost of car-

riage by mineral train in this country, it is found that the inclusive expenses incurred when sea-borne is only about $\frac{1}{15}$ of this figure. The passenger traffic yields figures scarcely less striking. A transatlantic passage, *including* board, costs 0·44*d.* per mile; the accommodation for the third class being luxurious as compared with that of a few years ago. Liquid fuel does not seem, on the whole, to be making headway, a fact which appears to be largely due to the existing monopolies in this valuable product.—**E. W. De Rusett, M.Inst.C.E.,** *Proc. Inst. Civ. Eng., Ap. 1904.*

Drilling Blast-Holes with Well Rigs.

In order to satisfy the demand for an inexpensive apparatus for drilling blast-holes on deep railway cuts, the Cyclone Drilling Machine Company, of Orrville, Ohio, began experiments to develop a type of well drill for this purpose. The first trials were made with the company's regular cable outfit, but while it was found that this would drill holes at a reduced cost, in many instances the holes drilled were as much too large as those made by other methods were too small, consequently, much of the explosive was blown out, and the cost of making the holes unnecessarily large was a complete waste of money. In loose material the constant caving and the dropping of pieces of rock was also a serious objection. Experiments were accordingly begun with hollow rod outfits, and after a few trials a modified form of this apparatus was found to answer the requirements. The machine finally devised will drill holes from $1\frac{3}{4}$ ins. to 6 ins. in diameter, through any kind of formation, the rods preventing loose rock from falling into the holes. Three-inch holes have been found most satisfactory for the greater part of the work, and the cost of sinking them is so much lower than with other systems for similar classes of railway cuts that more holes can be drilled for the same cost, thus enabling the rock to be broken up better by the blast. Where the spoil is loaded by a steam shovel this is a matter of some importance. The engine and boiler are mounted on the same truck with the drill frame, and can be moved by their own power. The plant has been designed for use by inexperienced workmen able to handle small engines.—**Anon,** *Eng. Rec., Vol. XCVI, No. 2503,* p. 779.

Heating from a Central Station.

This paper refers particularly to that class of station where coal is used as a raw material, to be manufactured into heat which is distributed through the streets of a city or town by means of suitable conduits, and sold to consumers. The following gives the estimated cost of producing 1,000,000 heat units at stations:—Price of coal per ton, in car lots, 2 dols.; heat units per pound, 12,000; efficiency of boiler plant (percentage), 60; cost of coal per million heat units, 0·137 dol.; cost for handling, at 12 per cent., 0·016 dol.; cost for depreciation, at 5 per cent., 0·007 dol.; total, 0·160 dol. The author discusses the various difficulties to be met and overcome in the management of a central heating-station, and states the essentials for a complete system of distributing mains. Tables are given (1) showing the heating rates for 1,000 lbs. of water; (2) for estimating the square foot of radiation in relation to temperature and the cubic foot of space to be heated with typical charges per square foot of radiation; and (3) rates for central-station heating. The author then discusses the value of exhaust steam from a lighting plant. The things to be considered in formulating an idea as to the best method to employ are next dealt with, and tables are given showing the operation of typical heating-plants. In conclusion the author expresses the opinion that, under the direction of good engineering advice, the business of heating from a central station will improve, and the hope that this paper has given reasonable grounds for believing that heating from a central station is a success when proper methods of business, with good engineering and apparatus, are used.—**W. H. Pearce,** *Jnl. Western Soc. Eng., Vol. IX, No. 1,* pp. 1–33.

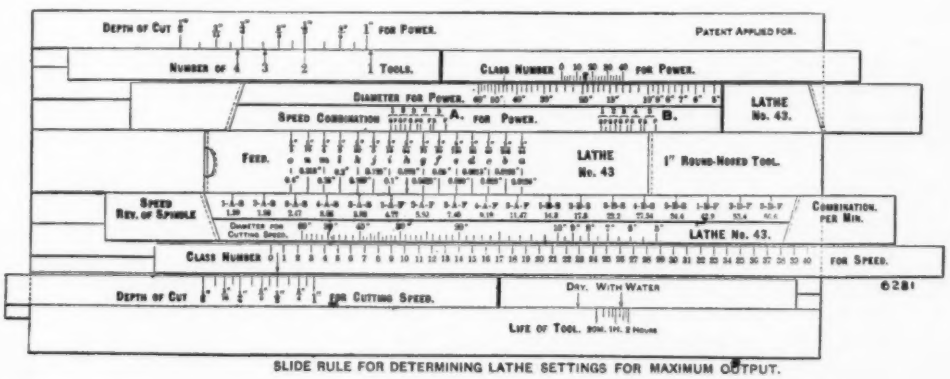
A Large Floating Crane.

A satisfactory test has recently been made by the United States Government of a new 100-ton floating crane which is one of the largest of this class of appliances in the world, and the entire structure is of open-hearth steel. The pontoon is 100 ft. long, 60 ft. wide, and 11 ft. deep; the bottom and sides are of $\frac{5}{8}$-in. plate, riveted to 12-in. channels spaced 2 ft. on centres; and the deck is $\frac{1}{2}$-in. plate, riveted to 8-in. channels. Two longitudinal water-tight bulk-heads divide the pontoon into three parts, the middle of which is a runway for the counterbalancing device. The two side portions are each sub-divided by two transverse water-tight bulkheads; in the middle division on the port side are two boilers, and in the corresponding part on the starboard side are the engines. The pontoon is designed to support the weight of the crane, the 100 tons lifted by the hoisting blocks, and, in addition, 300 gross tons of a deck-load—all with a free-board of 2 ft. The crane superstructure consists of the crane trusses proper and the supporting **A**-frames. The former are two Warren trusses 8 ft. deep and spaced 6 ft. on centres, with top chords of two channels. The bottom chords are plate-girders, on the lower flanges of which are laid four tracks, which form the trolley runway, extending the whole length of the trusses, a distance of 210 ft. There are four **A**-frames, two vertical and two inclined, each set being rigidly connected at the base. At the top the struts forming the inclined and vertical frames are riveted together, as well as to the trusses. Sixteen wheels support the trolley framework on the runways, and to this framework are fastened 4-ft. diameter steel sheaves, over which pass the hoisting ropes. The speed of vertical travel of the hoists is 50 ft. per min., and the trolley moves horizontally about 110 ft. per min., and these two motions are capable of being combined. The length of travel of the trolley is 190 ft., and the maximum height to which the blocks can be raised is 65 ft. above the mean draft-line of the pontoon,

the lower limit being 20 ft. below this line. The hoisting and travelling mechanisms are controlled by one engine with 12-in. cylinders and 15-in. stroke, connected, through a train of massive steel gears, to three drums, which are connected by friction clutches. A safety clutch operates in case any one of the cables slackens or breaks. The counter-weight is moved by a separate engine with 9-in. cylinders and 7-in. stroke. This engine is automatically started and stopped by a governor actuated by floats in two water-tight compartments. A safety device operates and locks this counter-weight in position in case the cable connected to its controlling engine breaks. Six water-tight compartments are used to trim a deck-load, and these are filled and emptied by means of a 6-in. centrifugal pump. Four steam capstans (one at each corner of the pontoon), four belts, and eight cleats complete the outfit of this large crane.—**J. S. Schultz,** *Eng. Rec., Vol. XLVIII, No. 25,* pp. 767, 768.

Slide Rules for the Machine Shop.

In this paper the author devotes attention to special forms of the slide rule, and more particularly to the slide rule designed for determining the feed and speed at which a lathe or kindred tool must be run in order to do a certain piece of work in a minimum time. He enumerates the variables that enter into the problem of determining the most economical way in which to remove a required amount of stock from a piece of lathe work, as follows—(1) The size and shape of the tools to be used; (2) The use, or not, of a cooling agent on the tool; (3) The number of tools to be used at the same time; (4) The length of time the tools are required to stand up to the work; (5) The hardness of the metal to be turned; (6) The diameter of the material or work; (7) The depth of the cut to be taken; (8) The feed to be used; (9) The cutting speed; (10) The cutting pressure on the tool; (11) The speed combination to be used to give at the same time the proper cutting speed, and the pressure required to take the cut; (12) The stiffness of the work. All these variables, except the last, are incorporated in the slide rule, which generally requires to be handled by a person with a good deal of practical experience and judgment. However, we expect some day to accumulate enough data, in regard to the relations between the stiffness of the work and the cuts and speeds that will not produce detrimental chatter, to do without personal judgment in this matter also. Of the eleven variables, all except the third and tenth enter into relations with each other that depend only on the cutting properties of the tools, while all except the second, fourth, and ninth also enter into another set of relations that depends on the pulling power of the lathe. The problem primarily solved by the slide rule is the determination of that speed-combination which will most nearly utilize all the pulling power of the lathe on the one hand, and the full cutting efficiency of the tools on the other, when values have been assigned to all the other nine variables. If our lathes were capable of making any number of revolutions per minute between certain limits, and the torque corresponding to this number of revolutions could be algebraically expressed in terms of such revolutions, then the problem might possibly be solved by ordinary algebraic methods; but as such driving mechanism is likely to be invented, the solution is necessarily one of trial and error, involving endless labour if attempted by ordinary mathematical methods; while it is a perfectly direct and remarkably simple one when performed on the slide rule. The slide rule, whose representation forms the main purpose of this paper, is illustrated in the figure here reproduced. A great deal of preliminary work has to be done before a lathe or other machine tool can be successfully put on a slide rule of the kind. The feeds, speeds, and pulling power must be studied and tabulated for handy reference, and the driving belts must not be allowed to fall below a certain tension, and must in every way be kept in first-



SLIDE RULE FOR DETERMINING LATHE SETTINGS FOR MAXIMUM OUTPUT.

class condition. In some cases it also becomes necessary to limit the work to be done, not by the pull that the belts can be counted on to exert, but by the strength of the gears. Having given an outline of the use of the slide-rule system of predetermining the feeds and speeds, etc., at which a machine tool ought to be run to do a piece of work in the shortest possible time, the writer adds that, in view of the results he has obtained, the usual way of running a machine shop appears little less than absurd.—**C. G. Barth, M.Am.Soc. M.E.,** *Eng. News, Vol. L, No. 24,* pp. 512–514.

Electro-magnetic and Electrostatic Separation of Minerals.

ALL apparatus for the electro-magnetic separation of minerals is based on the same principle. The mixed ore, crushed to a convenient size, is passed through a magnetic field of suitable intensity. The force exerted on the particles will be proportional to the magnetic induction, and therefore a function of their permeability. The resultant attraction for any particle will have the value $M\mu\left(\frac{1}{R^2}-\frac{1}{r^2}\right)$ where M is the magnetic mass of the poles, μ that of the particles, and R and r the distances of the latter from the poles. At first sight, to obtain the utmost effect, it only seems necessary to make the field as intense as possible, and pass the particles quite close to one of the poles; but as the poles are brought nearer together so as to reduce the air-gap, the negative term of the equation may increase more rapidly than the intensity of the field. The size of air-gap for which the attraction will be a maximum depends upon the permeability of the minerals dealt with, and can only be determined experimentally. For such as are strongly magnetic a considerable air-gap and a moderate distance between the path of the ore and the poles may be adopted. Another factor that has to be taken into account is the rate at which the mineral passes through the field. This has been demonstrated by the following experiment: A mixture of magnetite (strongly magnetic), rhodonite (slightly magnetic), and blende (very slightly magnetic) was passed through a magnetic field at various speeds by means of a travelling belt. At 100 metres per min. only the magnetite was influenced; the rhodonite was also slightly affected at 70 m. per min., and completely so at 50 m. per min.; while the blende did not commence to respond till the speed was reduced to 40 m. per min. When the speed was as low as 5 m. per min. the same effect could be produced on the blende with an expenditure of energy in exciting the electro-magnet only one-fiftieth that previously employed. Magnetic separators of different types may be classified according as their electro-magnets are fixed or movable. Under the first head they may again be subdivided into those where the magnetic mineral is lifted out of the mass during its passage through the field on some carrying device, and those in which the magnetic attraction deviates the line of flow of freely falling particles; while in some systems the mineral is both lifted and deflected at the same time. The separators under the second head are divisible into those whose action is intermittent and those where it is continuous. The author describes and illustrates separators that have proved successful in practice of all these various kinds, and in some cases gives figures of actual tests made to show the degree of separation that can be effected. He also deals with the quite recently introduced electrostatic separators for mixed ores which cannot be influenced magnetically, but may be selectively affected, according to their degree of conductivity, by condensers charged to a high potential.—**D. Korda,** *Soc. Intnl. Elecn., Vol. IV, No. 31,* pp. 9-41.—*E. J. W.*

Aerial Suspension-Cableways.

A CABLEWAY is defined as a device by which a suspended cable acts as a rail, on which travels a carriage provided with means of hoisting and lowering, so that a load may be conveyed to or removed from any point between the supports of the cable. The history of the cableway is traced generally, from the early machine used in the slate-quarries of Wales, having chains for standing and running cables, and a stop fixed on the main cable to bring the carriage to rest at the desired position, to the long-span, flexible, and high-speed cableway extensively used at the present day. Touching on the development of this apparatus, mention is made of the first "horizontal" cableway used in the Kemnay granite-quarry, and of the difficulties met with and surmounted before satisfactory results were obtained with that machine. The association of engineers and others in America with some of the improvements in cableway design is referred to. Various devices for supporting the hoisting-rope between load-carriage and cable-supports are mentioned, and are illustrated by diagrams. The type of engine and winding gear usually provided for operating a cableway is described, as are also the method of leading the ropes, the means by which a load is hoisted and lowered at any point, and the way in which horizontal motion is given to it at any height. Inclined, fixed, horizontal, travelling, and radial cableways are treated generally, and examples are given of the application of the various types to the construction of bridges, viaducts, waterworks, canal, and dock-works. For the last-mentioned purpose cableways used on the naval works at Gibraltar and on other dockyard extensions now in progress for H.M. Government and others are cited as examples. The application of cableways to quarrying, excavating, and conveying materials from one point to another, and to the transfer of coal and other materials between floating vessels—for instance, from a transport or collier to a battleship in the open sea—is then dealt with. Reference is also made to the advantages of the cableway, as compared with other means of handling materials in respect of speed of working, efficiency, convenience, etc.—**J. M. Henderson, A.M.Inst.C.E.,** *Proc. Inst. C.E., April, 1904.*